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IMPACTS OF THE BOWMAN-SPAULDING CANAL ON FOUR SIERRAM STREAMS: AN ECOLOGICAL AND GEOMORPHOLOGICAL EVALUATION

THESIS /REPORTS
ROSE, T

Impacts of the Bowman-Spaulding Canal on Four Sierran Streams: an Ecological and Geomorphological Evaluation

by

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Challenge Cost Share Agreement, USDA Forest Service File Code 2610,
"Evaluating the Impacts of Mid-Stream Water Withdrawal on Stream Morphology and Ecology"

UNIVERSITY OF CALIFORNIA, DAVIS

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October 8, 1996

Ann Carlson
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Tahoe National Forest
P.O. Box 6003
Nevada City, CA 95959

Dear Ann,

Enclosed is our final report for the Challenge Cost Share Agreement USDA File Code 2610 entitled "Evaluating the Impacts of Mid-Stream Water Withdrawal on Stream Morphology and Ecology." The title of the report is Impacts of the Bowman-Spaulding Canal on Four Sierran Streams: an Ecological and Geomorphological Evaluation. It is 107 pages with 31 figures and 13 tables.

We have received from Tami Rose the first draft of her manuscript for the FHR Currents Forest Service publication. Don Erman and I will review that manuscript and give our comments to Tami before it is sent to you.

It has been our pleasure to work with you on this project. If the data from the continuing emergence trap monitoring is promising, I will talk to you about continuing trap collections next year. Thank you to you and your field staff for all of your help in getting these valuable samples.

Sincerely,

Nancy Erman

Nancy A. Erman
Specialist/Lecturer
Aquatic Ecology

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INTRODUCTION

The study of human impacts on aquatic systems has grown due to both a reactive necessity and in response to a call for much needed base information. With the continued lack of information on the ecology of most species, biodiversity is much more endangered by human impacts than may have been recognized (Zwick 1992). This study concerns the evaluation of ecological impacts resulting from physical stream interception and flow diversion by a water transfer and collection canal on the Tahoe National Forest, California. Aquatic macroinvertebrates were selected as the target community for impact evaluation for several reasons: 1) the large number of species allows for community comparison (Ward 1992); 2) their relatively long life cycles allow for temporal specificity (Rosenburg and Resh 1993); 3) their relative immobility allows for distinct spatial effects of perturbations; 4) they are integral to the physical structuring of ecosystems (Wallace and Webster 1996); and 5) most importantly, aquatic insects often make up most of an aquatic community. The objectives of this study were to :

1) Collect baseline channel profiles, bank heights, and particle size distributions on the four study streams, upstream and downstream of the Bowman-Spaulding Canal. Use this data to evaluate the impacts of the canal on stream channel forms and processes.
2) Assess the ecological impacts of the canal on the study streams by evaluating diversity, abundance and natural history of macroinvertebrate communities upstream and downstream of the canal.
3) Outline a monitoring plan for the U.S. Forest Service in order to provide further base-line data and to track physical and ecological impacts from the canal on stream and watershed systems.

4) Provide general restoration alternatives for the study streams with disturbed ecosystems or impaired geomorphology that may affect stream reaches beyond the immediate study area.

The Bowman-Spaulding Canal directly affects the downstream hydrology of the intercepted streams through flow interception and occasional increased peak flows from canal discharges. Peak flows have important effects on streams geomorphology, including channel form and bed material size. The vast majority of sediment transport occurs during peak flows (Ritter 1978, Garde and Rauga Raju 1985). The ability of the stream to transport incoming sediment will determine deposition or erosion zones within the active stream channel. This link between sediment load and sediment transport capacity will affect the distribution of habitat types, channel morphology and bed material particle size. The stable particle size of bed material is determined in large part by peak flows, being larger the higher the peak flows (Grant 1987). Large, stable particles generally provide important habitat space for fish and invertebrates, while a highly unstable bed will reduce periphyton and invertebrate production (Hynes 1970).

Changes in sediment load and/or peak runoff can also affect the overall elevation of the thalweg (the deepest point of a stream channel) profile through aggradation or degradation, and alter the structure and habitat types along the profile (Beschta and Platts 1986). An increase in sediment load can fill pools and decrease channel gradients (Sullivan et al. 1987). A decline in sediment results in channel incision. Channel incision can lead to bank steepening and bank instability, increasing the sediment load into the channel (Beschta and Platts 1986).

Flow dynamics have been expressed as the most important factor affecting stream communities (Hynes 1970, Statzner and Higler 1986, Minshall 1988, Statzner et al. 1988, and Poff and Ward 1989). Statzner et al. (1988) have shown that flow parameters directly influence benthic densities, thus any alteration of the distribution, frequency, or availability

of preferred hydraulic conditions could alter the dynamics of benthic communities. Further, the degree of ecological disturbance resulting from high discharges is directly dependent upon the existence of hydraulic refugia and the movement patterns of benthic species (Gore et al. 1994). McElravy et al. (1989) found that extreme events such as drought or high rainfall accounted for the greatest variability in benthic fauna distributions. Resh et al. (1988) have suggested that the degree of impact from flood events may be related to its predictability. Thus high flow events which have long, or varied periods without disturbance may cause greater community damage than if those flows were more regular. Poff (1992) refined the argument of Resh et al. (1988) by defining disturbance of stream communities as flows large enough to move substrates, regardless of their statistical regularity.

The streams in this study are composed of permanent and intermittent streams, however, the canal has created intermittency on permanent streams and has increased the degree of intermittency on non-permanent streams. With decreasing inflow from the corresponding watershed, intermittent stream habitats shift from well connected, flowing water to small isolated pools (Chapman et al. 1991). This habitat shift increases the stress to organisms to deal with periods of low or no flow. The general mechanisms used by aquatic organisms to inhabit temporary waters include having a resistant life stage (drought resistant eggs, or pupal cases); utilizing an adult, terrestrial stage during dry periods; or instream movement to a more desirable habitat (Abell 1956, Delucchi and Peckarsky 1989). These mechanisms could result in unique species to intermittent streams, or in species which inhabit both permanent and temporary streams but utilize different mechanisms for each environment.

STUDY AREA

The Bowman-Spaulding Canal serves as a water transfer and collection canal for the Nevada Irrigation District (NID). The canal delivers water from Bowman Lake to Fuller Lake, from where it is then transferred to Lake Spaulding through a pipeline. The canal length from Bowman to Fuller Lake is 14.6 km, and begins at an elevation of approximately 1640 m at Bowman Lake and ends at approximately 1624 m elevation at Fuller Lake. The canal is concrete lined and entrenched into the hillside most of its length, with some segments tunneled through steep rock outcroppings and an elevated section spanning the channel of Fall Creek.

The canal directly intercepts five streams between Lakes Bowman and Fuller: Texas Creek, Clear Creek, Fall Creek, Trap Creek, and Rucker Creek (Figure 1). This study was conducted on four of the five creeks: Clear Creek, Fall Creek, Trap Creek and Rucker Creek; all direct or indirect tributaries to the South Fork Yuba River. Clear Creek originates from snowmelt runoff at an elevation of 1878 m. It flows westward 3,300 m through moderately sloped forest before reaching Bowman Canal at approximately 1,626 m elevation. It continues downstream of the canal at a slightly more moderate grade for 1500 m where it flows into Fall Creek (Figure 2). Clear Creek is an intermittent stream, with flow ceasing in the upstream reaches by October of this study period. Impacts on the Clear Creek watershed include logging, logging roads and a recreational, instream mining claim coinciding with the downstream sampling reach used for this study. The mining impact was discovered after the sampling program had begun.

Fall Creek originates from a series of two man-made reservoirs, Feely and Carr Lakes, with the downstream outlet at approximately 2,020 m. It flows 5,630 m downstream through steep to moderately steep forests before reaching the canal. Fall Creek continues downstream of the canal, ultimately through a very steep canyon before

entering the South Fork Yuba River (Figure 2). Fall Creek is a permanent stream and had flow upstream of the canal throughout the study period. Watershed impacts include historic logging and mining, logging roads, and a paved road with a culvert crossing upstream of the study area.

Trap Creek originates as snowmelt at approximately 1685 m elevation. It flows 970 m downstream through moderately sloped forests until reaching the Canal. It continues 1900 m. downstream, through gradually increasing sloped terrain until entering the very steep Fall Creek Canyon and eventually Fall Creek (Figure 2). Trap Creek is an intermittent stream. The upstream reaches were dry by October of this study period. The Trap Creek watershed has impacts from logging roads, a paved road crossing with an associated culvert and fairly recent evidence of logging upstream of the study site.

Rucker Creek begins at the outlet of Rucker Lake, the lower of two reservoirs on the stream, and has a spillway elevation of 1655 m. It flows 40 m through gentle slopes until reaching the canal. The canal location coincides with a bedrock shelf, which causes a break in slope on the Rucker Creek watershed. The gradient downstream of the shelf is steep all the way to the confluence with the South Fork Yuba River, 1515 m downstream (Figure 2). Rucker Creek, upstream of the canal has permanent flow due to releases from Rucker Lake. The impacts on the Rucker Creek watershed include logging, logging roads, a paved road, and a culvert crossing.

The Bowman-Spaulding canal follows the contours of the hillslopes, bisecting each streams at approximately a 90 degree angle. The canal top edge is set at ground level, forcing flow from the streams to enter and follow the course of the canal. Flow release gates from the canal to the downstream portion of the creeks, normally kept closed, exist at Clear, Trap and Rucker Creeks. Fall Creek is not diverted directly by the canal, but rather by a check dam, from which a diversion canal runs water to the Bowman Spaulding Canal. Thus water from the canal can be released to the downstream reaches of Clear, Trap and

Rucker Creeks but not Fall Creek. The downstream portion of Fall Creek receives only non-diverted water from the upstream portion of Fall Creek.

The Canal diverts all of the upstream flow of the intercepted creeks for most, but not all of the year. During the spring high flows, part of Fall Creek is allowed to flow downstream, through an open weir structure in the check dam. During this study, this structure was closed, forcing all of Fall Creek into the canal, by the end of May 1995.

Releases to the downstream portions of Trap and Rucker Creeks occur only during specific events: to relieve the canal discharge if it is too full, or to empty the canal during annual cleaning of sediment and boulders. The canal is operated such that it is at maximum capacity (320 cfs) at the tunnel to Fuller Lake, just downstream of the Rucker Creek interception. During the spring high runoff period, the canal flow is unpredictable due to snow melt variability and resulting flows from the intercepted creeks. If the canal begins to overflow, water is discharged down the flow release gates on Trap and/or Rucker Creeks. Annual maintenance and cleaning of the canal was conducted at the end of July 1995 during this study. Approximately 125 cubic feet per second (cfs) were spilled down Trap Creek for 8 hours, and 30 to 40 cfs spilled down Rucker Creek for 4 hours (Dick Eckenberg, NID, personal communication). Other than these events, there was no flow contributed to the downstream portions of these creeks. There was, however, ground water-fed flow on the downstream portion of Fall Creek during the entire study period, and some ground water-fed pools during part of the spring and summer on Trap and Rucker Creeks.

The release gate on Clear Creek is not opened often or on a regular basis (Dick Eckenberg, NID, personal communication). The gate, however, has a leak, allowing a small yet steady flow downstream all year long. By fall 1995, Clear Creek was dry naturally upstream of the canal, but was flowing downstream of the canal.

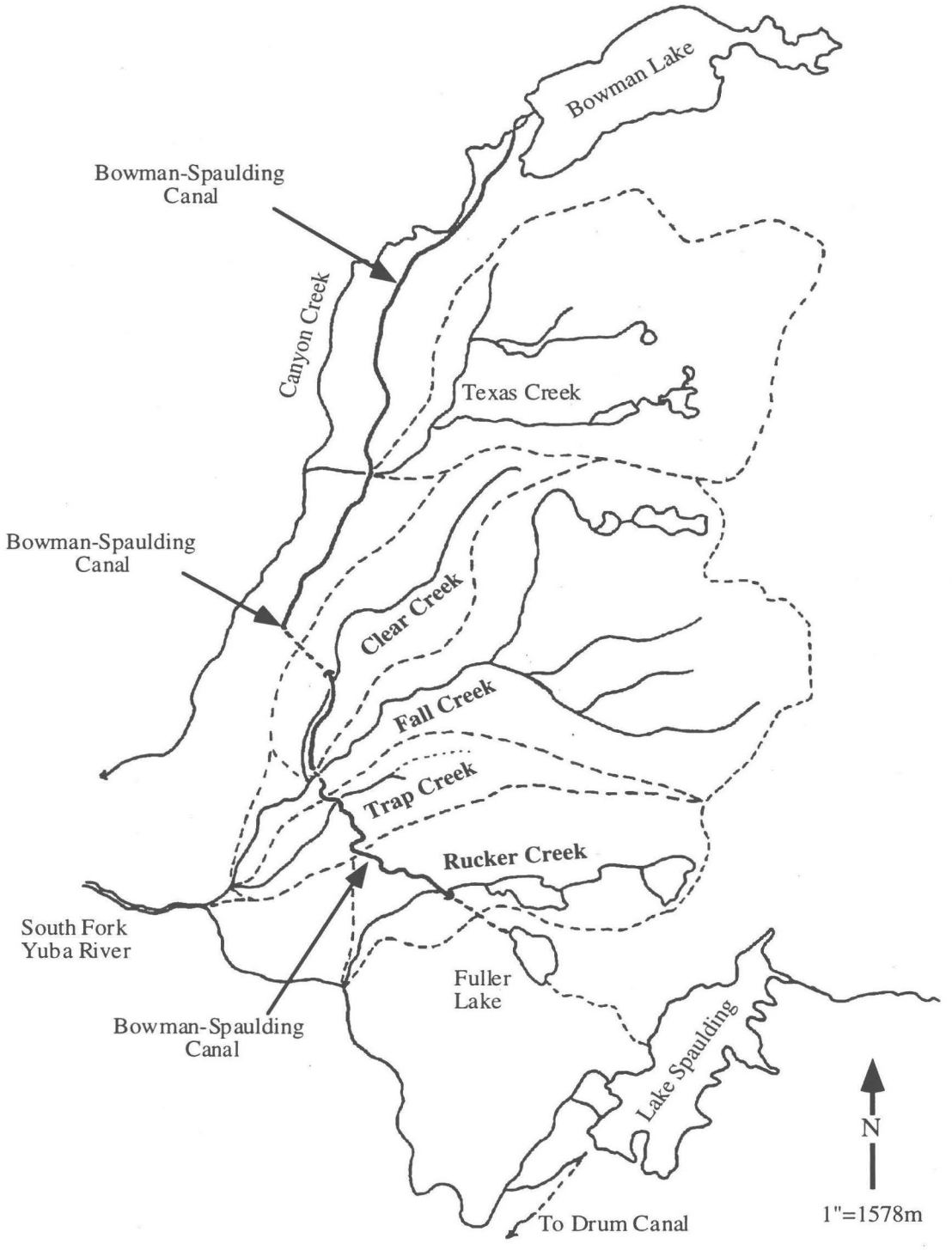

Figure 1. Location map of study area, showing streams, watershed boundaries, reservoirs, and the Bowman-Spaulding Canal.

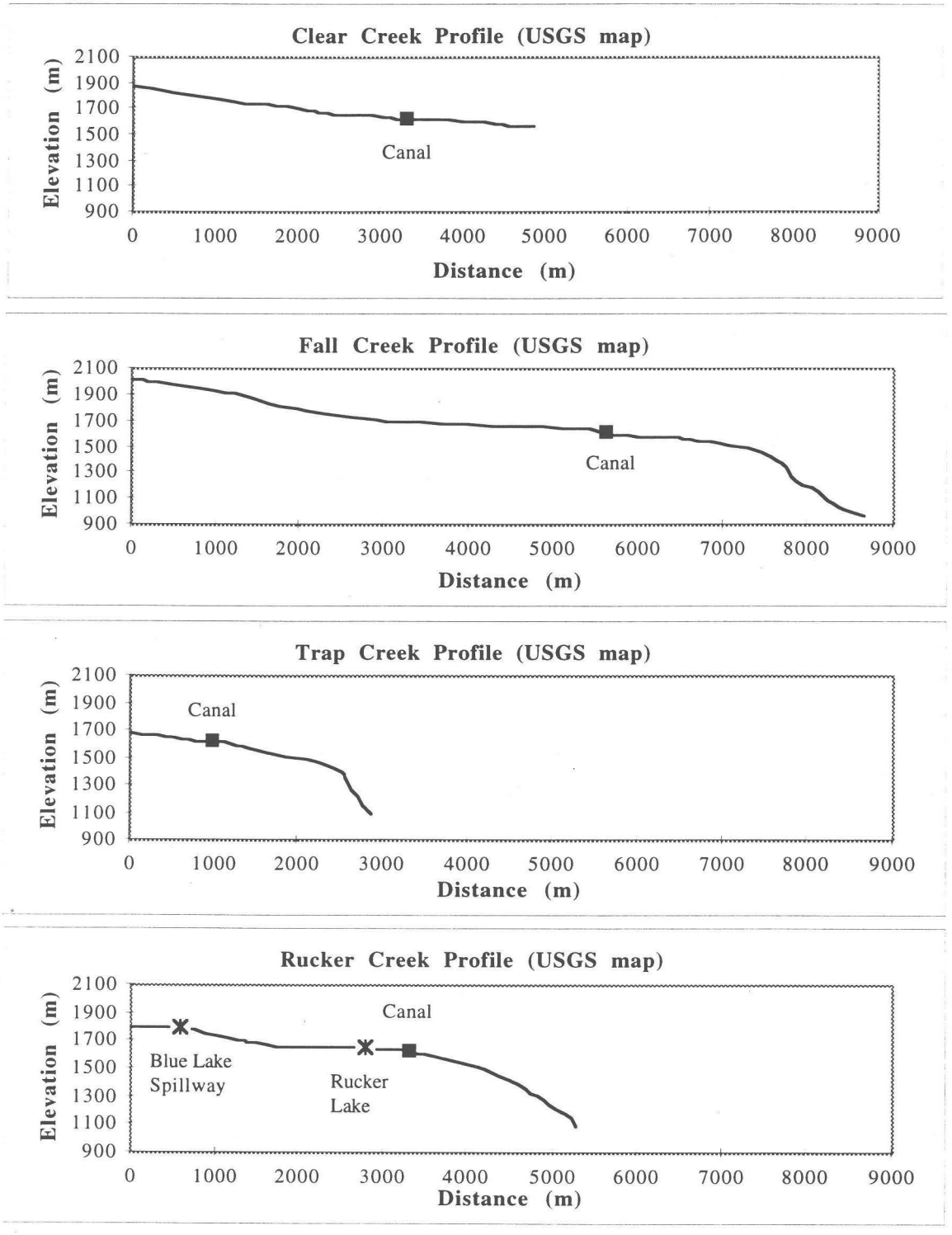

Figure 2. Creek profiles based on USGS topographical maps (7.5' "Blue Canyon" and "Graniteville"

METHODS

Transect Layout

Transects and reaches were established for all study streams. Continuous reaches of 50 m lengths along the thalweg were measured and staked; five upstream of the canal and five downstream. Longitudinal profiles were surveyed along all reaches and cross-sectional surveys were conducted at the ends of all reaches. Reaches were numbered from 1 to 10, upstream to downstream, with 1 through 5 upstream of the canal; and reaches 6 through 10 downstream of the canal (Figure 3).

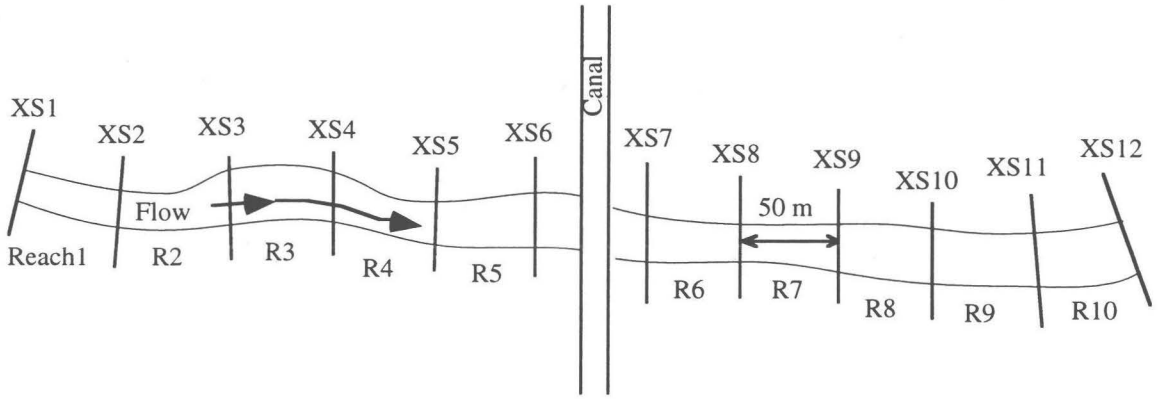

Figure 3. Reach and cross-section layout on streams.

Water quality, flow, and invertebrate samples were collected in one reach upstream and one reach downstream of the canal on all streams. The upstream sample was always taken from the reach directly upstream of the canal, Reach 5. The downstream reach was selected as the first reach which contained flowing water. If none of the reaches downstream of the canal met this condition, the farthest downstream reach was selected for data collection (in isolated pools). Clear Creek always had water flowing directly

downstream of the canal due to the small leak in the spill gate; thus the sample reach was the first one downstream, Reach 6. Fall Creek had a small amount of leakage from the diversion gate, yet continuous flow did not exist until mid-Reach 9. Reach 10 was chosen as the sampling reach for Fall Creek. Trap Creek was completely dry downstream of the canal on all site visits. Isolated pools existed in Reach 10, thus it was chosen as the downstream sampling reach. Rucker Creek, also completely dry directly downstream of the canal, had isolated pools existing in Reach 10, thus it was also selected as the sampling reach.

Physical Sampling

Discharge and water quality measurements were collected approximately every two weeks between June 14, 1995 and November 19, 1995. Discharge was derived from velocity and channel cross-sectional measurements using a Marsh McBirney (model 201D) portable water current meter. Temperature and conductivity were measured with a Hach conductivity/TDS meter (model 44600). A Corning pH meter (model 106pH) was used to measure pH.

Particle size data was gathered by direct measurement on reaches 1, 3, 5, 6, 8, and 10 on Clear, Trap, and Fall Creeks and on Reaches 5 and 10 on Rucker Creek. One hundred particles per reach were collected at random by walking down the thalweg at low flow, blindly selecting a particle with a finger tip then measuring the intermediate axis (Wolman 1954). The data were plotted as frequency analysis, or percent finer graphs to compare relative size distributions among reaches in each stream. The median (d_{50}), 16% (d_{50}), and the 84% (d_{84}) particle sizes were averaged for upstream and downstream reaches to determine difference in particle size distribution upstream and downstream of the canal.

The amount and size of large woody debris in channels were catalogued in each study reach for Clear, Fall and Trap Creeks. Large woody debris was defined as organic matter at least 10 cm in diameter and 2 m long (Bilby and Ward 1989). A piece was counted as being in the channel if any part was touching the channel bottom or within the channel banks. A mean volume per piece of wood was estimated by calculating the volume of a cylinder having as its dimensions the geometric mean debris diameter and length. Average total volume indices were calculated for each reach, and statistical comparisons of average volume-index per reach between upstream and downstream reaches were made using paired t-tests.

Biological Sampling

Macroinvertebrate samples were collected at the same sites as the flow and water quality data collections. Three methods of collection were used: hand net sampling, artificial substrates, and emergence traps. Five hand net collections were made randomly, in moving water along the sample reach. The hand net was 32 cm. x 54 cm., 1.0 mm mesh. The net was placed in the stream before disturbing an area of approximately 200 cm^2 directly upstream with a trowel for approximately 15 seconds. Samples were picked in the field and preserved in 80% ethanol. Hand net collections were made approximately every two weeks from 11 June 1995 through 19 November 1995. The five collections per sampling event were preserved separately, but treated collectively as one sample for data analysis.

Artificial substrates were used for sampling in order to minimize sampling differences due to diversity in substrate composition, to reduce sampling method variability (Rosenberg and Resh 1982), to have a sampling option if hand net samples were not possible in low velocity, late summer flows and as a quantitative comparison. The artificial

substrate samples were collected using 21 cm x 9.5 cm x 3 cm paver bricks. Paver bricks were selected as the substrate after qualitative experimentation was done on a variety of artificial substrates. On June 13 and 14, 1995, Italian, unglazed tiles; Mexican unglazed tiles; and paver bricks were set out in groups of three (one of each) in the two sampling reaches on all streams. Observations of tile and brick colonization were made on June 27 and July 1, 1995. Though colonization was low on all artificial substrates, the brick substrates had observably more invertebrate colonization than the tiles (no invertebrates were on the Italian tile, one invertebrate was on the Mexican tile, 4 invertebrates were on bricks).

Twenty-four bricks were placed randomly in moving water in each stream sample reach on July 7 and 8, 1995. Three bricks were selected from each site at subsequent sampling times. Invertebrates were removed by hand in the field and preserved in 80% ethanol. The sampled bricks were taken from the field, with the remaining bricks left in the stream for future sampling, thus allowing for uninterrupted colonization throughout the data collection season. Artificial substrate samples were collected approximately every two weeks from July 31, 1995 through September 12, 1995.

Late in July, the bricks in the downstream reach of Trap Creek were washed out of the channel with the high flows released from the canal for maintenance. To coordinate the subsequent sampling on Trap Creek, all upstream bricks and recovered downstream bricks were removed from the stream for approximately 24 hours during the August 1, 1995 sampling period. The bricks were returned to both sampling reaches on the same day after the drying period.

Emergence traps, in groups of three, were placed in the upstream and downstream data collection reaches on Fall Creek and Trap Creek. Emergence traps were made with redwood frames and 1.4 mm mesh, with a 1 m^2 capture opening (Erman and Erman 1990). Traps were placed on Fall Creek on July 31, 1995; and on August 25 on Trap

Creek. Samples from the emergence traps were collected approximately every week between 12 August and 19 November 1995 for Fall Creek and between 6 September and 19 November 1995 for Trap Creek.

Invertebrate samples from all collection methods were taken to the laboratory where hand-net and artificial substrate samples were identified to genus and emergence trap samples were identified to order (Merritt and Cummins 1984, Stewart and Stark 1993).

Data Analyses

Biotic indices were calculated for all sites and sampling times and comparisons made among sites. Taxa richness, Shannon diversity, Shannon evenness, and number of individuals collected (Magurran 1988) were calculated.

Correlations between biotic indices and physical parameters (percent of study period in which a stream had flow, average velocity, mean particle size, channel slope, and peak temperature), were made with multiple regressions using the StatView 512+ program. Values of biotic indices and physical parameters which were collected over time were averaged for the regression analysis.

Similarity comparisons were made among all sites using the Jaccard's index (Pielou 1984). This value ranges from 0, having no taxa in common, to 1, in which two sites would have all taxa in common.

Comparisons among the three sampling techniques (benthic, artificial substrate, and emergence trap) were made at the order level. Data were compared as percent abundance values over common sampling intervals.

RESULTS

Physical

A summary of the stream flows and chemistry (temperature, conductivity and pH) is given in Table 1. Mean flow data was calculated from flow measurement made in the field. The data given for estimated flow range were based on observations and discussion with NID personnel. Water quality data collected on each sample date is provided in Appendix A. Table 2 summarizes geomorphologic aspects of the study streams and sample reaches. Elevations of the study reaches are given as general elevational ranges of the canal taken from 7.5' USGS topographical maps. More precise elevations were not available for the area. Gradients were calculated from surveys of the stream channels done as part of this study, rather than from USGS maps.

Table 1. Summary of mean physical-chemical water parameters.

Stream	Flow (cfs)	Flow Range (measured)	Flow Range (estimated)	Temp. (C)	Temp. Range	Cond. (uS/cm)	Cond. Range	pH	pH Range
Clear u/s	3.8	0-18 (18)		10.8	4.2-13.9 (9.7)	13.4	12-20.5 (8.5)	6.4	5.8-7 (1.2)
Clear d/s	0.5	.1-2.5 (2.4)	.1-6 (5.9)	11.0	6.1-14.1 (8)	17.8	15-25.5 (10.5)	6.4	5.8-6.9 (1.1)
Fall u/s	24.5	2.2-90 (87.8)		10.6	4.8-15.9 (11.1)	29.6	12.7-49 (36.3)	6.6	6.3-7 (.7)
Fall d/s	2.9	.1-16 (15.9)		10.4	4.7-14.8 (10.1)	31.0	15.2-40.6 (25.4)	6.8	6.4-7 (.6)
Trap u/s	0.9	0-5.1 (5.1)		10.0	5.9-13.3 (7.4)	16.1	11.8-20.3 (8.5)	6.8	6.4-7.2 (.8)
Trap d/s	0.2	0-1.5 (1.5)	0-125 (125)	11.9	8.1-14 (5.9)	35.9	19.3-44.7 (25.4)	6.7	6.2-7 (.8)
Rucker u/s	2.1	.3-5.8 (5.5)		16.4	10.6-20 (9.4)	13.5	11.1-16.4 (5.3)	6.9	6.5-7.1 (.6)
Rucker d/s	0	0 (0)	0-40 (40)	11.6	7.8-12.9 (5.1)	46.8	36.9-54.4 (17.5)	6.7	6.7-6.7 (0)

Table 2. Summary of geomorphological parameters of streams and study reaches.

Stream	Stream Order	Watershed Area (km^2) (@ canal & total)	Elevation (m)	Gradient (%)	Sample Reach (SR)	SR d_{50} (cm)	SR d_{84}-d_{16} (cm)
Clear, u/s	2	5.2	1620-1630	2.9	5	7	2.7-14
Clear, d/s		6.0		4.4	6	.8	.2-21
Fall, u/s	2	15.3	1620-1630	3.4	5	9	2.5-23
Fall, d/s		27.2		9.1	10	15.5	4-65
Trap, u/s	1	1.6	1620-1630	5.6	5	12	.5-39
Trap, d/s		3.6		10.4	10	15	1.1-200
Rucker, u/s	1	5.7	1620-1630	4.9	5	16	3-39
Rucker, d/s		8.3		13.5	10	32	10-63

Clear Creek

The stream flows and temperatures during the study period for the upstream and downstream sample reaches of Clear Creek are shown in Figure 4.

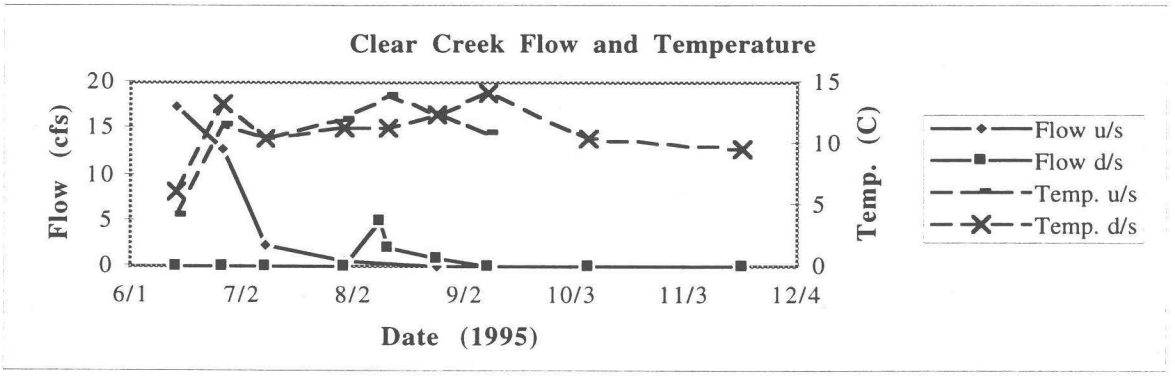

Figure 4. Clear Creek flows and temperature on upstream and downstream reaches.

The upstream flow during the study period peaked at 17.5 on June 14, 1995 and ceased flowing by the October 7, 1995 sampling date. The flow in the downstream reach varied between 0.1 cfs and approximately 5 cfs with no seasonal trend. On the August 12, 1995 sampling date, a higher flow existed on the downstream section than had been observed previously. An object was found to be lodged under the spill gate, thus allowing

more flow down the creek (2 cfs on that date). However, there was also evidence that a higher flow had recently occurred of approximately 2 to 3 times the 2 cfs flow. This conclusion was based on the level of bank wetting and vegetation disturbance along the channel, and was verified by discussions with NID personnel, who had opened the spill gate in an attempt to wash out the debris from under the gate. A conservative estimate of 5 cfs was made for 2 days prior (August 10, 1995) to the observation date.

The temperatures of the upstream and downstream reaches did not differ significantly. Temperatures are inversely proportional to the amount of flow as expected. Spring and early summer high flows are from direct snow melt, thus temperatures are low. The upstream temperature range was from 4.2 ^{o}C to 13.9 ^{o}C, while the downstream temperature range was between 6.1 ^{o}C to 14.1 ^{o}C.

The longitudinal and cross-sectional survey results for Clear Creek are shown in Figures 5 and 6. The longitudinal profile reveals a small increase in slope from upstream to downstream reaches (2.9% and 4.4% respectively). This may be due partially to sediment storage, shown in the profile, for 100 meters (reaches 4 and 5) upstream of the canal and channel erosion for about 100 meters (reaches 6 and 7) below the canal. The canal retards and intercepts the natural movement of sediments down the channel, thus causing deposition at the upstream edge. This deposition flattens the slope of the channel bottom, which further decreases the energy of the stream flow, causing deposition further upstream. The slight scour downstream of the canal is caused by a deprivation of sediment movement to that portion of the channel from upstream sources. Further, any water that is released from the canal to the downstream reach has no sediment load, thus high energy, and erosive.

The cross-sectional surveys (Figure 6) also reveal deposition upstream and evidence of erosion downstream of the canal. Cross-section 1 through 4 have a channel width of approximately 10 meters and depth of 2 to 3 meters. Cross-section 5, and 6

reveal a wider, shallower channel with an average depth of less then 1.5 meters and an average width of 14 meter. The first two cross-sections downstream of the canal, 7 and 8, indicate that the channel has an average width of 13 meters and depth of 2.5 meters. This reach is as wide as the reach directly upstream, but deeper by 1 meter. Cross-sections 9 through 12 have an average width of 8.4 meters and a depth of 1.7 meters, a channel shape approaching that of reaches 1, 2, and 3 upstream.

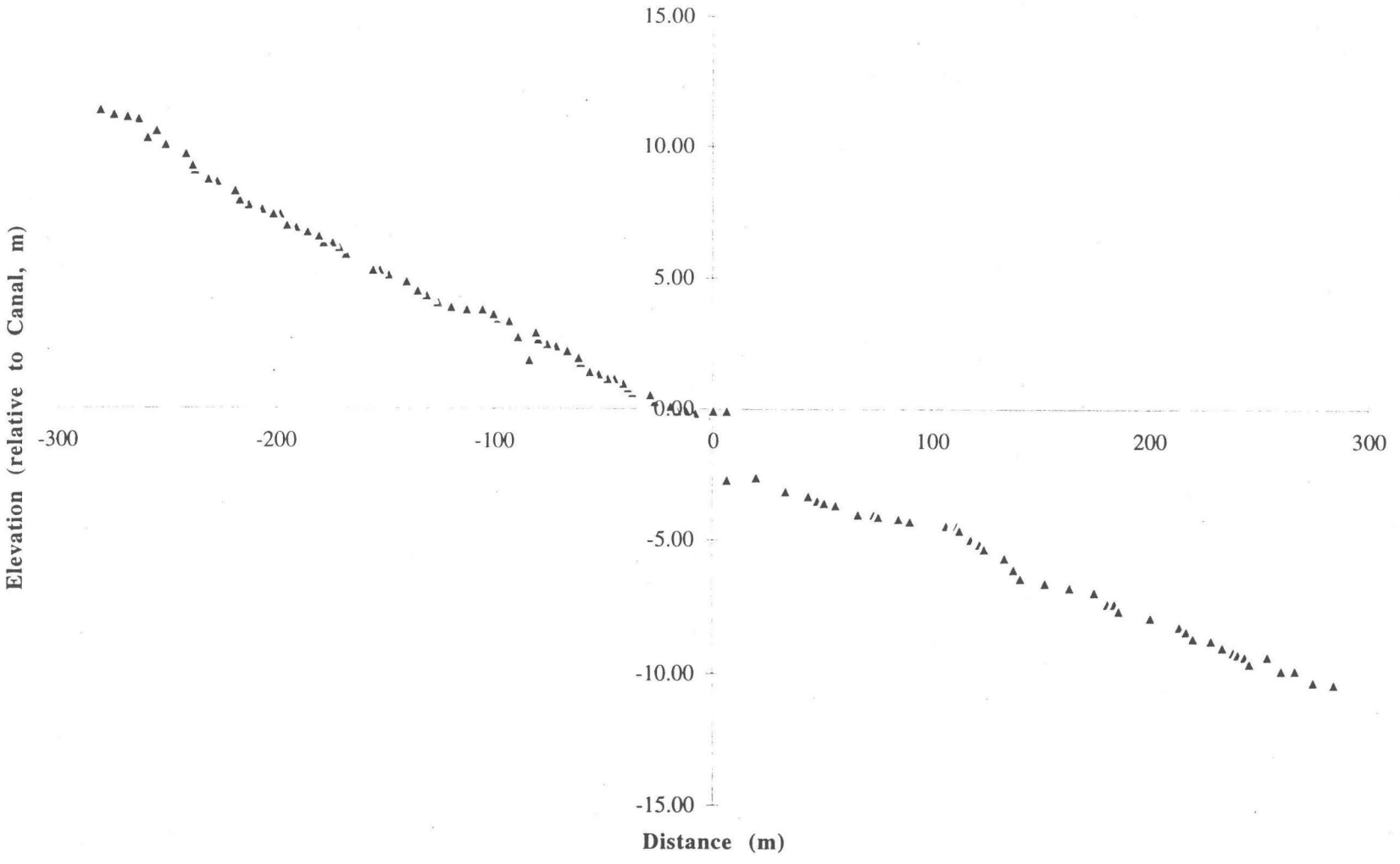

Figure 5. Clear Creek longitudinal profile.

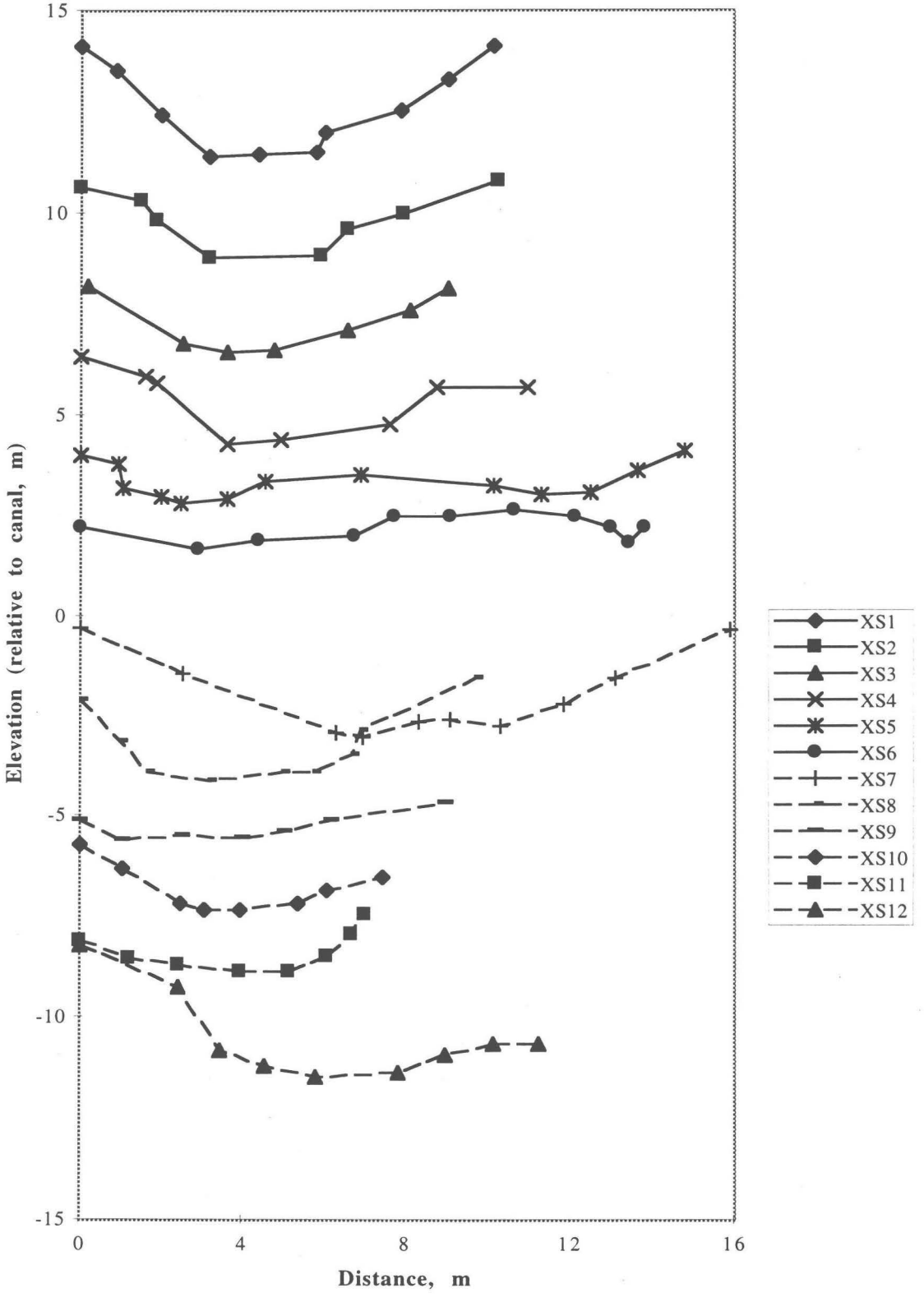

Figure 6. Clear Creek surveyed cross-section.

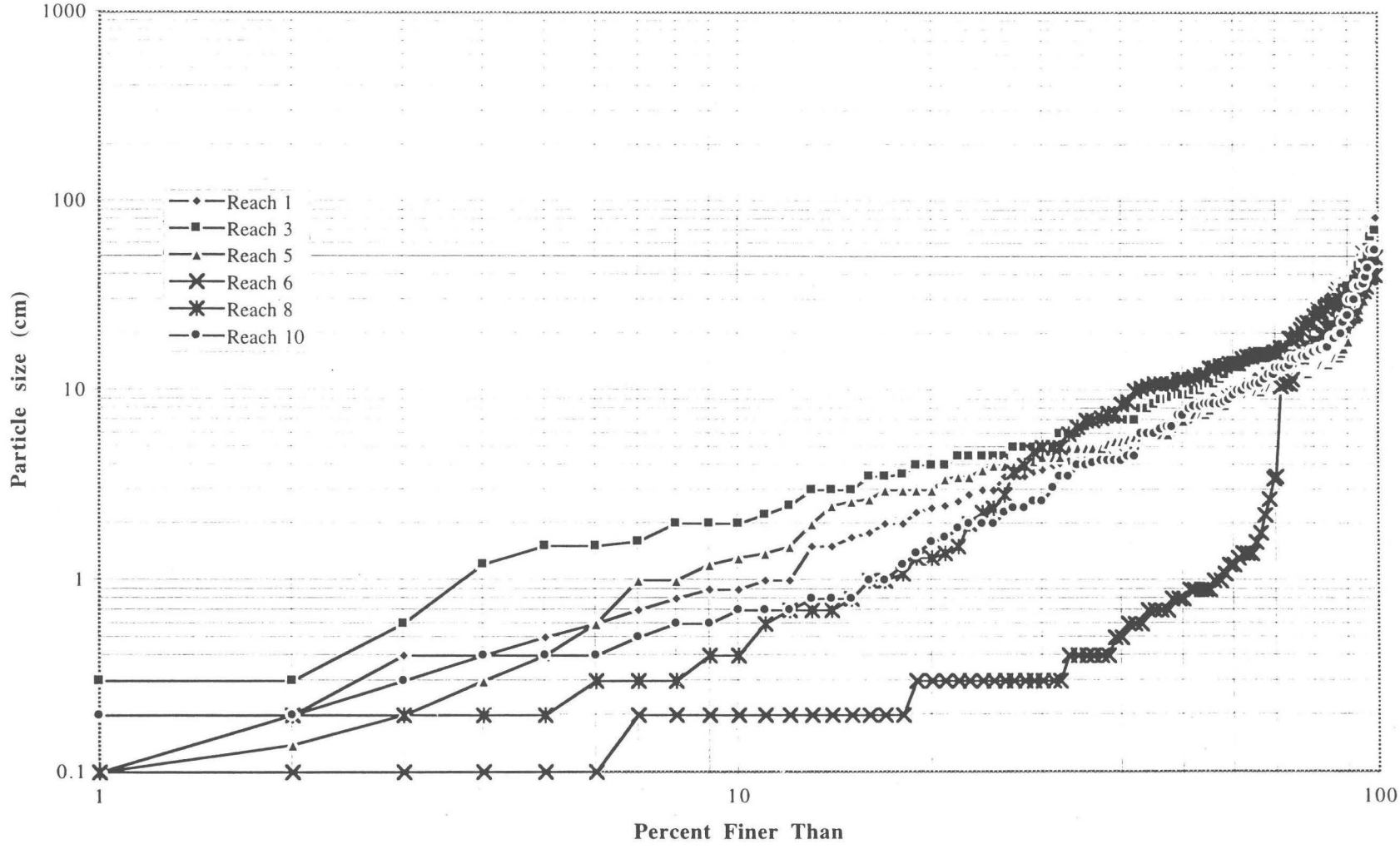

Figure 7. Clear Creek particle size distribution.

The particle size analysis for Clear Creek can be seen in Figure 7 and is summarized in Table 3.

Table 3. Summary of Clear Creek Particle Size Analysis (R=reach, u/s=upstream, d/s=downstream)

	R1 (cm)	R3 (cm)	R5 (cm)	u/s mean	R6 (cm)	R8 (cm)	R10 (cm)	d/s mean
d_{16}	1.8	3.5	2.7	2.7	.2	1	1	.7
d_{50}	7	9.5	7	7.8	.8	11.5	7.3	6.5
d_{84}	3.2	22	14	22.7	21	28	17	22

The average of the median particle size (d_{50}) is similar in the upstream and downstream reaches, with the range biased towards the smaller particle size in the downstream study area. This is also shown in the graphical description (Figure 7), where the upstream d_{50}s are all greater than the downstream values. There are two probable reasons for this. The downstream section had not recently received flushing flows (Dick Eckenberg, NID, personal communication), thus smaller sediments were not moved downstream, as they were in the upper section of stream. The second factor affecting the sediment distribution is that reaches 6 and 7, immediately below the canal, have an elevated input of small, decomposed granite particles from the canal road which crosses the upstream end of the reach 6, and the high, steep banks on both reaches (Figure 6). The road is situated higher than the channel elevation and has steep, erosive slopes down to the channel. The erosive channel sides have also been exacerbated by historical channel downcutting. Thus the downstream channel shows evidence of long-term scouring, but also a depositional zone for road gravel.

Fall Creek

Fall Creek has the largest watershed area of the study streams, and the highest and longest lasting flow (Figure 8). The measured peak upstream flow was 90 cfs in June 1995, tapering off to a base flow of between 3 and 4 cfs during August and September. The temperature range upstream was from a low of 4.8 in June to a high of 15.4 in August.

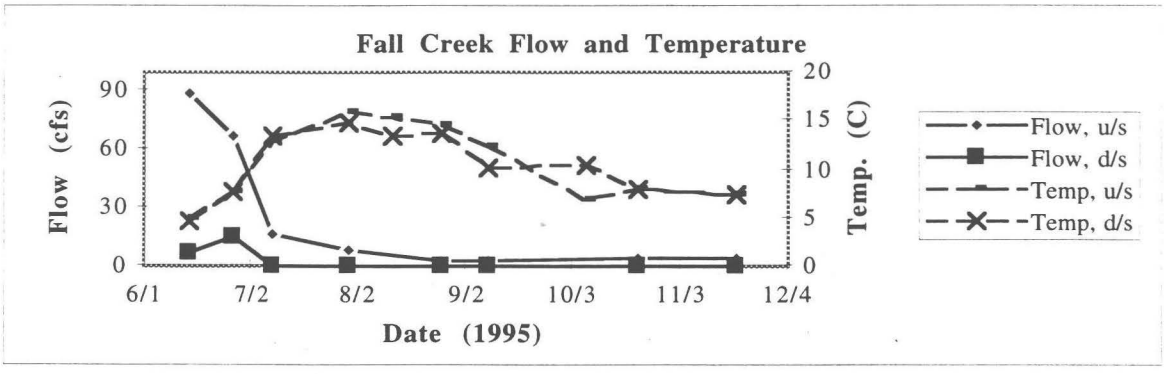

Figure 8. Fall Creek flows and temperatures of upstream and downstream reaches.

The downstream flow varied slightly at the beginning of the study period, as NID was changing the level of the check dam outflow structure (changing the amount of flow diverted to the Bowman-Spaulding Canal). The peak bypass flow to the lower section of Fall Creek was 15.5 cfs. The check dam was completely closed by the July 9, 1995 sampling date, and no flow was released to the downstream reaches. However, ground-water contribution to the channel supported consistent summer flows of approximately 0.1 cfs in reaches 9 and 10. The downstream temperature range was between 4.7 ^{o}C in June, peaking at 14.8 ^{o}C at the end of July. The peak temperature downstream was approximately one degree C less than the upstream peak, due to the ground water inflow.

The longitudinal and cross-sectional surveys for Fall Creek can be seen in Figures 9 and 10. Some evidence of a depositional zone 100 meters upstream of the canal can be

seen in the profile. As mentioned, Fall Creek has a check dam placed over the entire width, from which a portion, to all the flow is diverted into the canal. Any flow let down Fall Creek is released though an adjustable height weir-like structure, mid-width of the impoundment. By partially impounding and slowing the flow of the stream, the dam causes sediments to drop out, a cascading effect which has occurred upstream for approximately 100 meters. Deposited sediments are usually flushed from a reach during high flows, however, with the dam in place, little of the sediment can pass over or through the weir during high flow events.

Downstream of the canal, the channel has a much steeper slope than upstream (9.1% vs. 3.4%). Three factors could explain this. The deposition in the last two upstream reach flattens out the channel slope upstream; the immediate downstream reaches are sediment starved because of the sediment storage behind the impoundment; and natural factors. The impoundment has been constructed at a natural narrowing of the channel through a cut in a bedrock shelf. A "back-up" of gravels, cobbles, and boulders could have occurred over a longer time scale than that of the canal. This long term deposition upstream and scouring downstream has probably been exacerbated by the impoundment which further impedes the flow of sediment downstream. The narrow cut has also caused the channel to be more confined upstream of the canal. Steep hillsides come right down to the channel, while the downstream section has a wider area for the channel to form. This is evident in the Fall Creek cross-sections (Figure 10). The channel appears to be slightly wider downstream where it is not confined, yet it is also deeper due to the increase in slope and decrease in sediment transport from upstream.

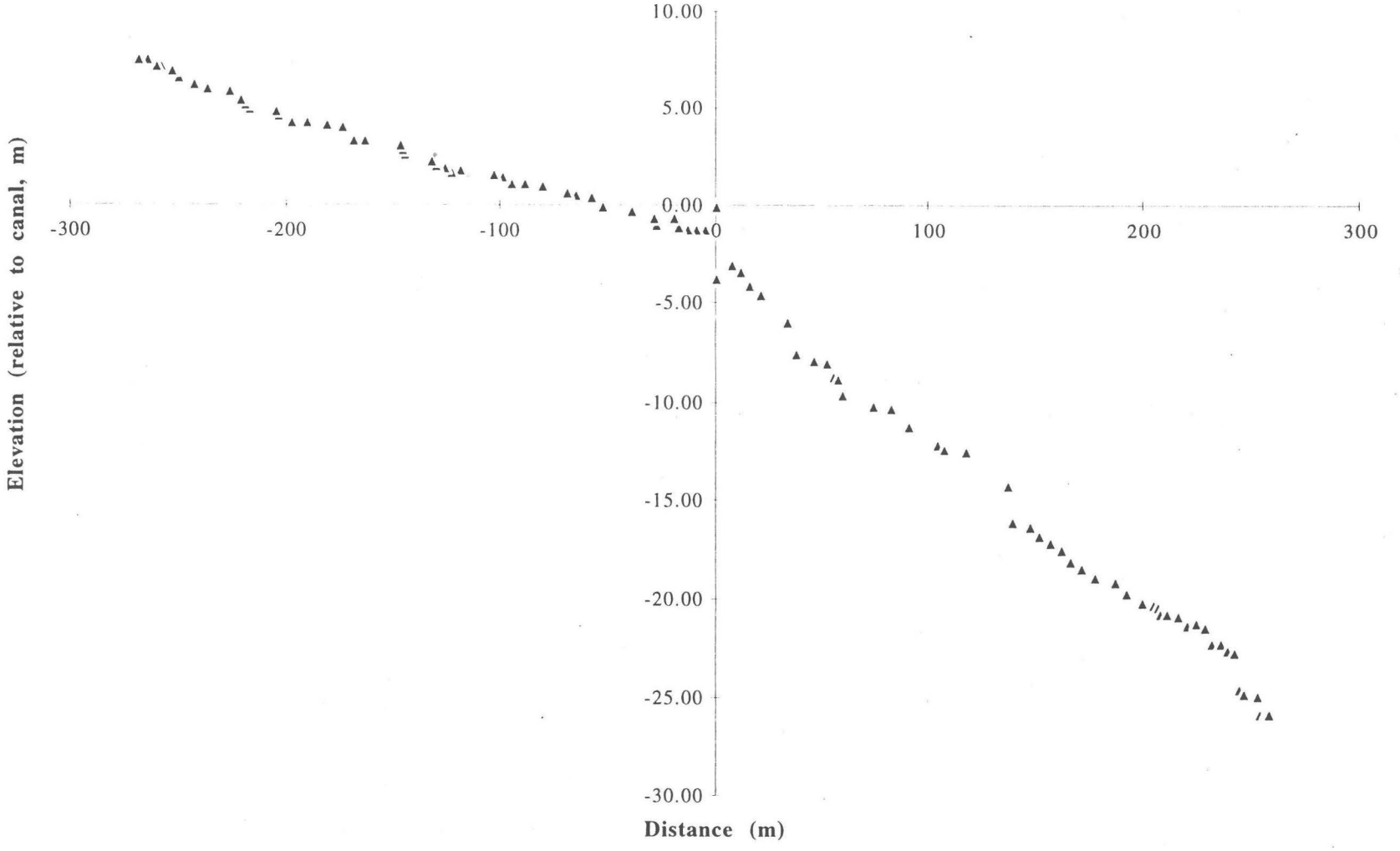

Figure 9. Fall Creek longitudinal profile.

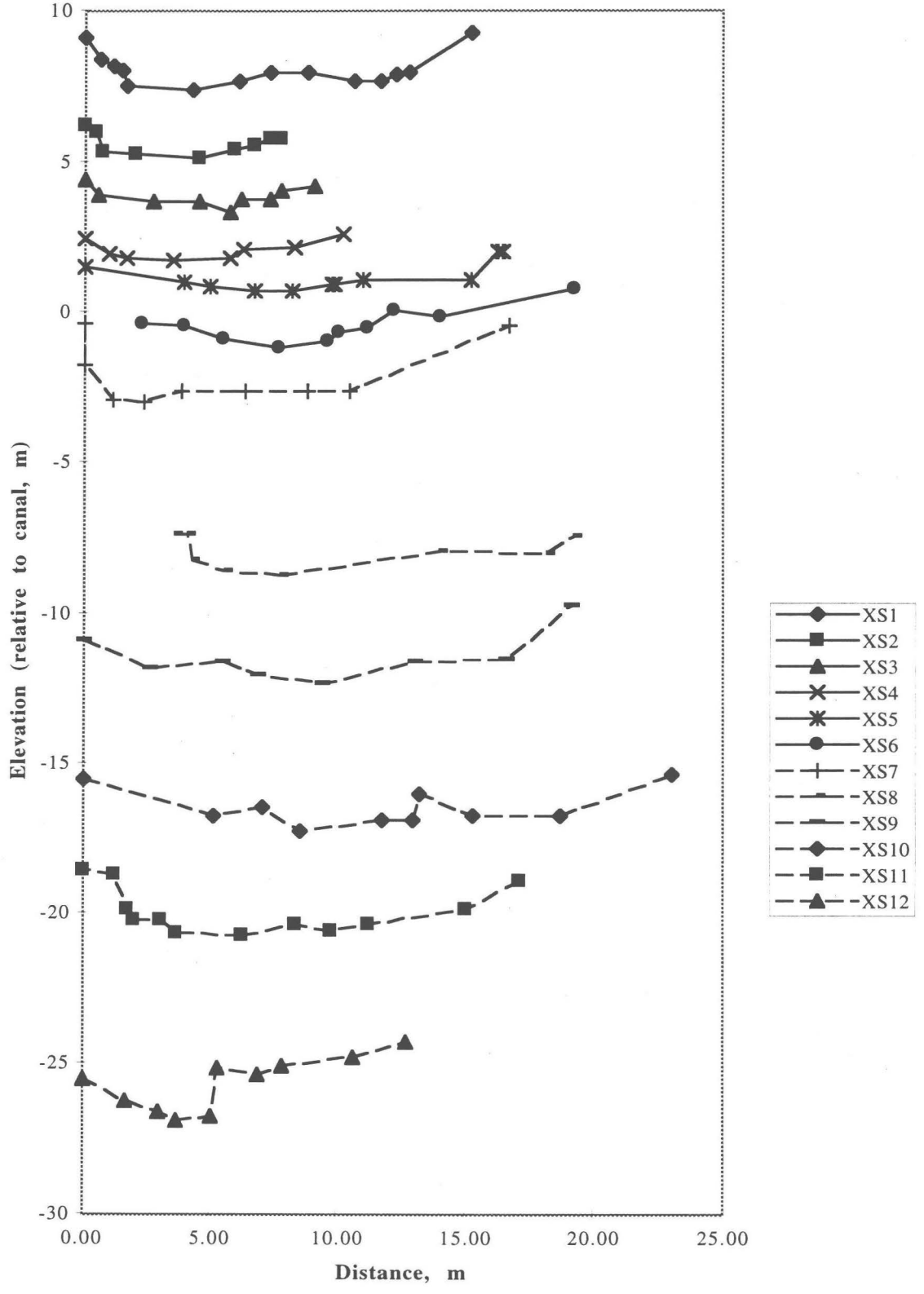

Figure 10. Fall Creek surveyed cross-sections.

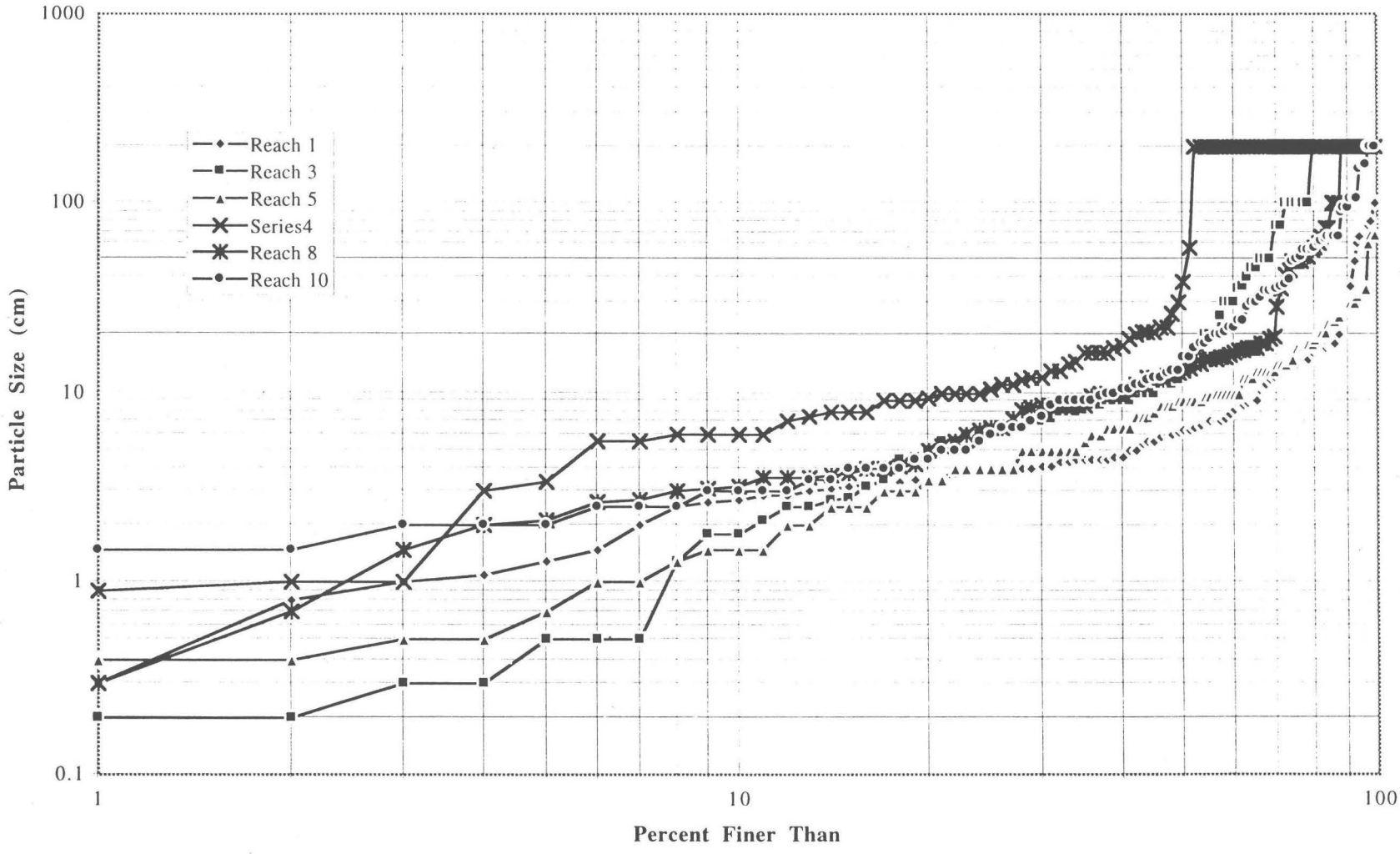

Figure 11. Fall Creek particle size distribution.

The particle size distribution for Fall Creek can be seen in Figure 11 and is summarized below in Table 4.

Table 4. Summary of Fall Creek Particle Size Analysis.

	R1 (cm)	R3 (cm)	R5 (cm)	u/s mean	R6 (cm)	R8 (cm)	R10 (cm)	d/s mean
d_{16}	3.3	3.2	2.5	3.0	8	4	4	5.3
d_{50}	6.3	13	9	9.4	38	13	15.5	22.1
d_{84}	18	200	23	80.3	200	74	65	113

The mean of the median particle size for the three sampled upstream reaches (9.4 cm), is much smaller than for the three sampled lower reaches (22.1 cm). The upstream reaches were dominated by course gravel and small cobbles, while the downstream reaches were dominated by large cobbles. The transport of bedload particles from the upper section is hindered by the check dam, thus "starving" the lower sections of these small cobble-sized particles. Both the upper and lower sections have several bedrock outcroppings (greater than 200 cm size class). Granite bedrock is especially prevalent in Reach 6, just below the check dam, and is associated with the rock ledge creating the constriction of the channel.

Trap Creek

Trap Creek has the smallest watershed area among the study streams. The peak flow was measured as 5 cfs (Figure 12). A small base flow of between .6 and .01 lasted from July 9, 1995 to September 9, 1995. By the October 7, 1995 sampling date, however, the upstream reached had ceased flowing, with only a few small pools remaining. The upstream temperature range was between a low of 5.9 to a high of 13.3 ^{o}C.

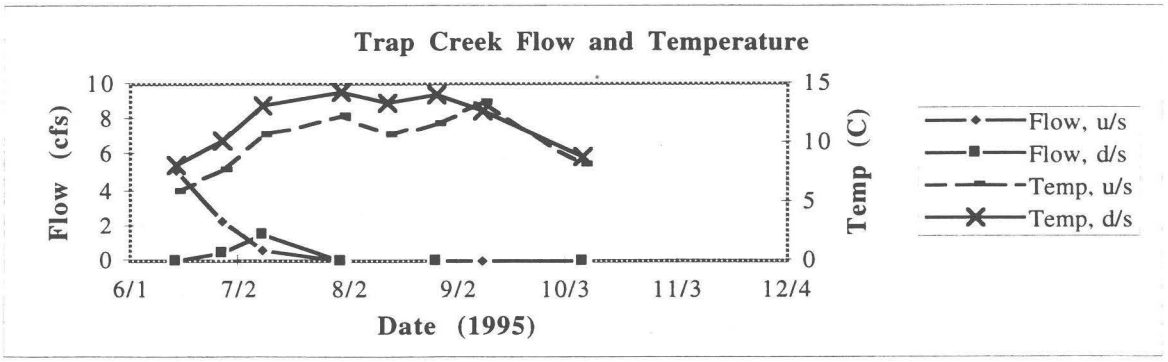

Figure 12. Trap Creek flows and temperatures of upstream and downstream reaches.

As previously mentioned, the downstream reaches of Trap Creek receive no water from the canal on a regular basis. The first evidence of water in the channel existed as ground water-fed pools in Reach 10. These pools had enough water early in the season to have flow between the upstream and downstream series, thus flow measurements were taken in June and early July. The flows ranged from .04 on June 14, 1995 to 1.5 cfs on July 9, 1995. These flows may also be influenced by unplanned releases from the canal, which may occur for maintenance and/or flow regulation of the canal.

The Trap Creek longitudinal and cross-sectional surveys are shown in Figures 13 and 14. It is evident that scouring has occurred for approximately 100 meters downstream of the canal. This phenomenon is especially strong in Trap Creek because the flows released into the downstream sections have been much greater than the high flows experienced by the upstream channel. For example, when the canal was being serviced in July, 1995, approximately 125 cfs was released down Trap Creek for 8 hours (Dick Eckenberg, NID, personal communication) . The highest flow measured in the upstream portion of the canal was 5 cfs. This was not an annual peak flow, but was near bank-full discharge during the spring melt. The historic channel of Trap Creek was formed by flows much smaller (and less instantaneous) than the flows which have been released to the lower channel since the canal construction. In addition to being elevated flows, the discharge to

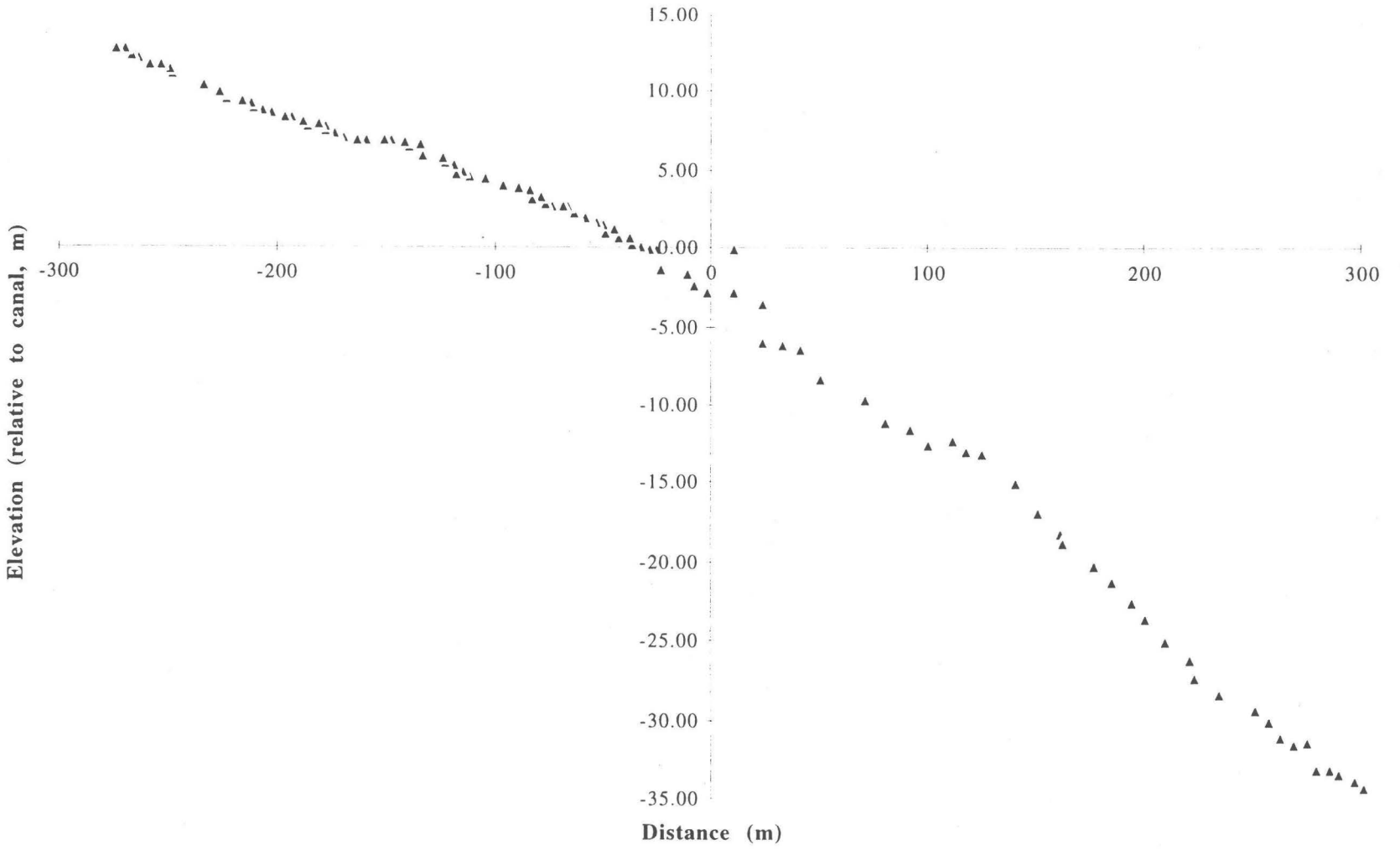

Figure 13. Trap Creek longitudinal profile.

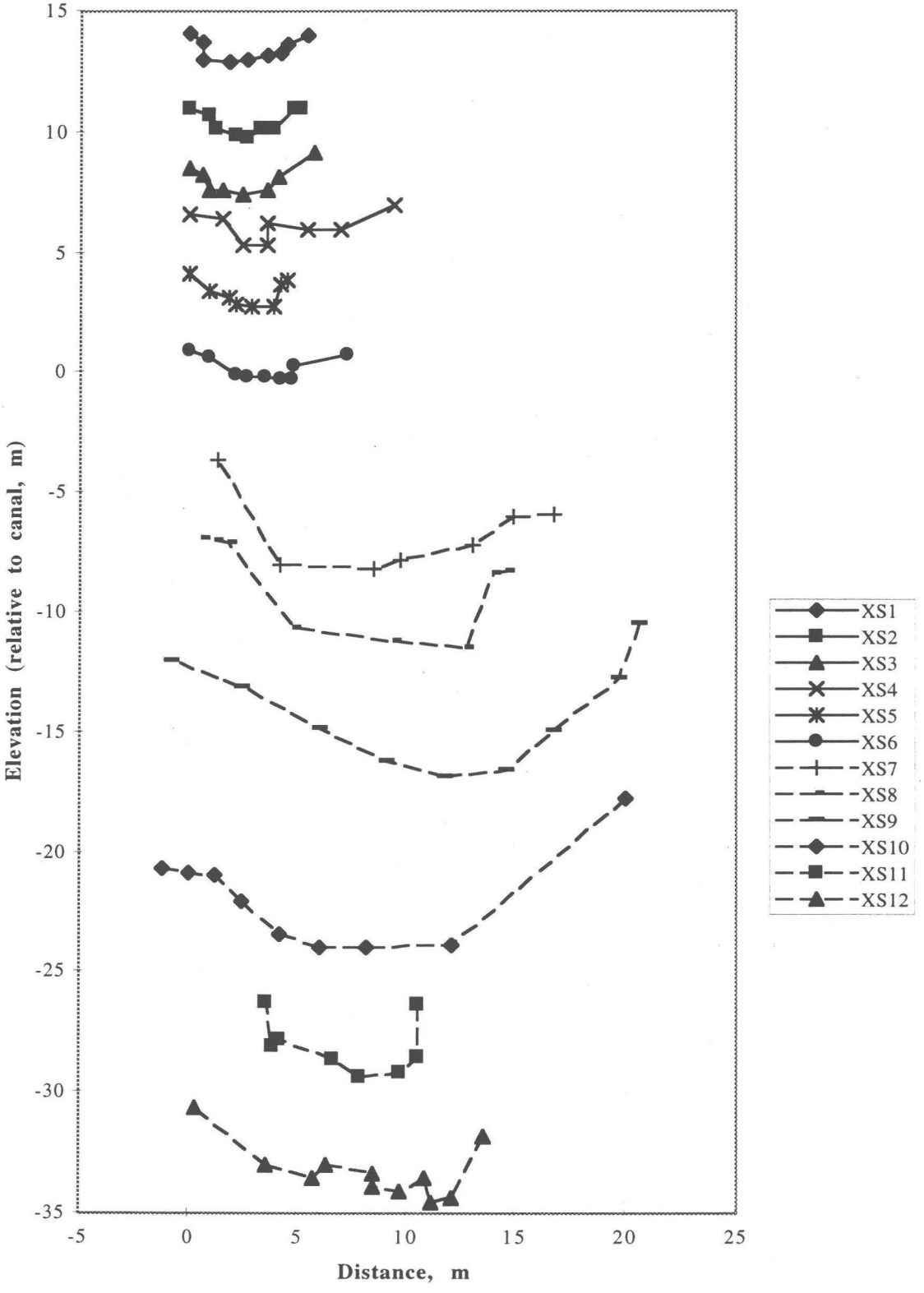

Figure 14. Trap Creek surveyed cross-sections.

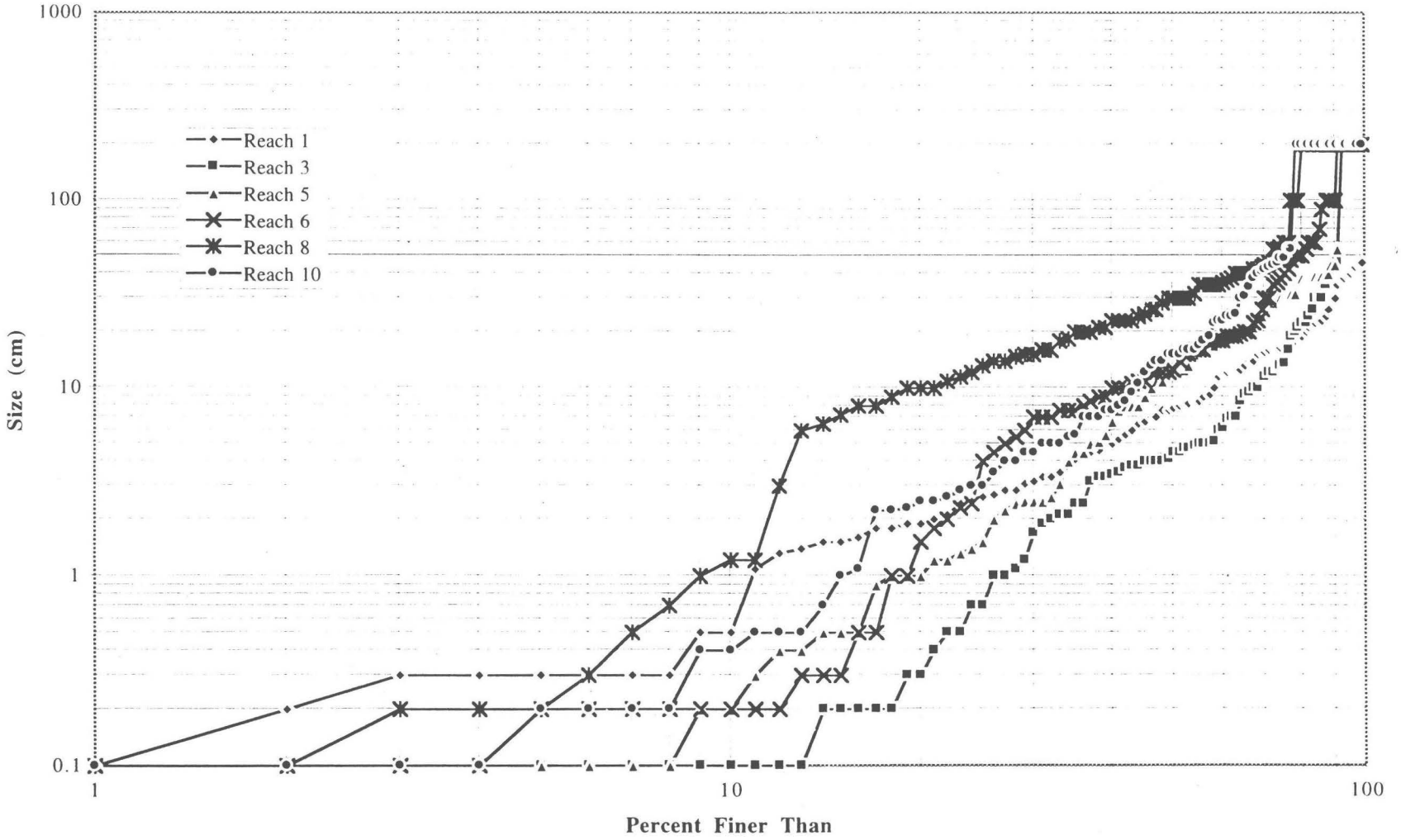

Figure 15. Trap Creek particle size distribution.

the downstream portion of Trap Creek has been even more erosive due to the lack of sediment load carried by the flow, creating very high energy water from the canal.

The cross-sections of Trap Creek also show a difference in channel shape between the upstream and downstream study reaches. The width of the channel doubles and the depth approximately triples downstream of the canal. The channel banks of these reaches are also very unstable and severe erosion (sloughing of channel banks) has and is occurring.

The particle size distribution for Trap Creek is shown in Figure 15 and is summarized in Table 5.

Table 5. Summary of Trap Creek Particle Size Analysis.

	R1 (cm)	R3 (cm)	R5 (cm)	u/s mean	R6 (cm)	R8 (cm)	R10 (cm)	d/s mean
d_{16}	1.6	.2	.5	.8	.5	8	1.1	3.2
d_{50}	7.8	4.5	12	8.1	12.5	30	15	19.2
d_{84}	22	30	39	30.3	60	200	200	153

The mean of the median particles sizes downstream (19.2 cm) is twice that of upstream (8.1 cm) stream sections. The upstream reaches can be described as ranging from fine gravel to large cobbles, with the median type being small cobbles. The downstream reaches can be described as having dominant particles ranging from coarse gravels to large boulders with the median being large cobbles. The downstream channel contains many large cobbles and boulders. This debris has sloughed into the channel from the eroding channel banks and is too large to be transported further downstream.

Rucker Creek

The measured hydrograph for Rucker Creek differs slightly from the other streams (Figure 16). Flows in the upstream reaches are directly supported by releases from Rucker Lake. The descending limb of the hydrograph is not as smoothly tapered as in Clear, Fall, and Trap Creeks. The upstream flow also lasted longer than those creeks of similar sized watersheds (Clear and Trap), and even had a significant increases towards the end of the study period due to flow manipulations. The downstream portion of Rucker Creek receives no consistent flow from the canal. There was no evidence of water downstream of the canal until Reach 10. There were isolated pools here, with no flow among them and they lasted only through the August 13, 1995 sampling date.

The temperature of Rucker Creek upstream of the canal was the warmest of all study streams, with a range from 10.6 ^{o}C to 20 ^{o}C. The release water from Rucker Lake warms up during the summer months due to the shallow nature of the lake. The temperature of the pools in the downstream reach ranged from a low of 7.8 ^{o}C in June to 12.9 ^{o}C in August.

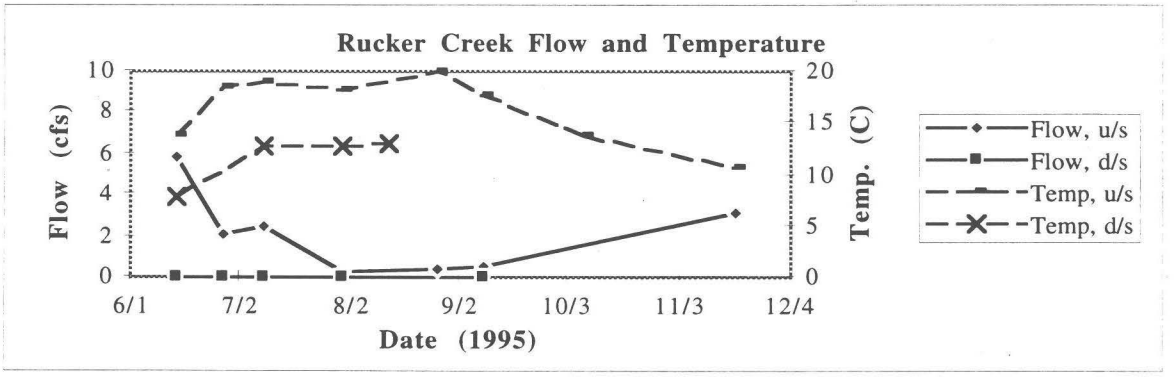

Figure 16. Rucker Creek flows and temperatures for upstream and downstream reaches.

The canal crosses and diverts Rucker Creek just below a bedrock shelf, below which the slope increases dramatically and Rucker Creek makes its way down steep grades to the South Yuba canyon (Figure 2). This dramatic increase in slope from upstream to downstream of the canal (4.9% to 13.5%) may be due predominantly to the natural break in slope. However, as can be seen in the longitudinal and cross-sectional surveys (Figures 17 and 18), a 100 meter long scour hole has formed below the canal. Rucker Creek below the canal experiences extreme flows similar to the lower reaches of Trap Creek. Periodic flows are released down Rucker Creek during canal overflows or canal maintenance. These flows are flashy, with dramatic increases and decreases in velocities; and are high energy due to the lack of sediment load.

The particle size analysis results for Rucker Creek are shown in Figure 19 and below, in Table 6.

Table 6. Summary of Rucker Creek Particle Size Analysis.

	Reach 5 (cm)	Reach 10 (cm)
d16	3	10
d50	16	32
d84	39	63

The median particle size downstream is twice that of the upstream section, with the dominant range including much larger particle sizes as well. From this data, the upstream study area can be classified as having a particle size range dominant in coarse gravel to small boulders, with the mean composed of large cobbles. The downstream can be described as having a particle range dominant in small cobbles to medium boulders with the mean composition of small boulders. The increase in range and mean particle size for the downstream reach is indicative of the sediment starved, erosive flows that are released from the canal.

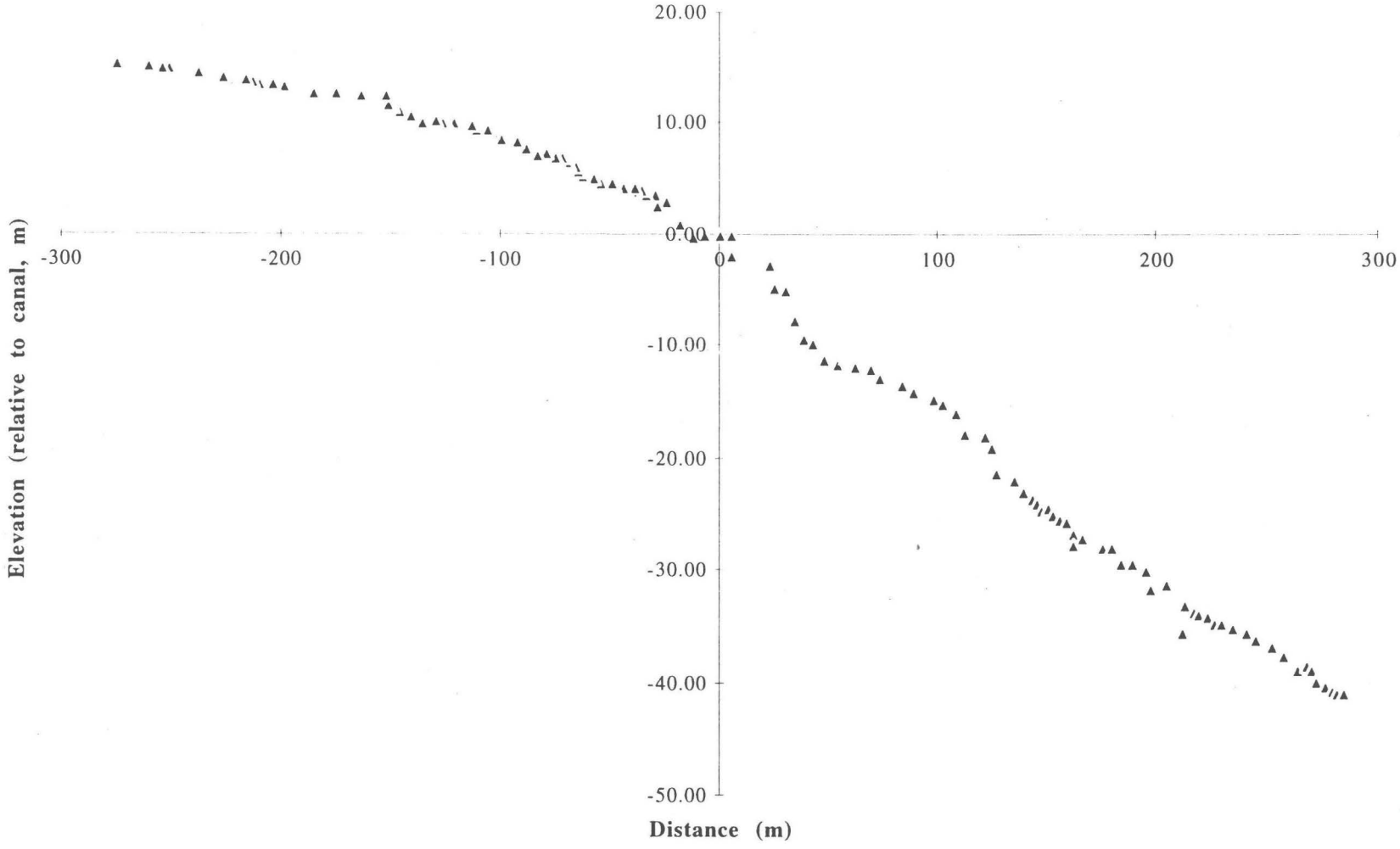

Figure 17. Rucker Creek longitudinal profile.

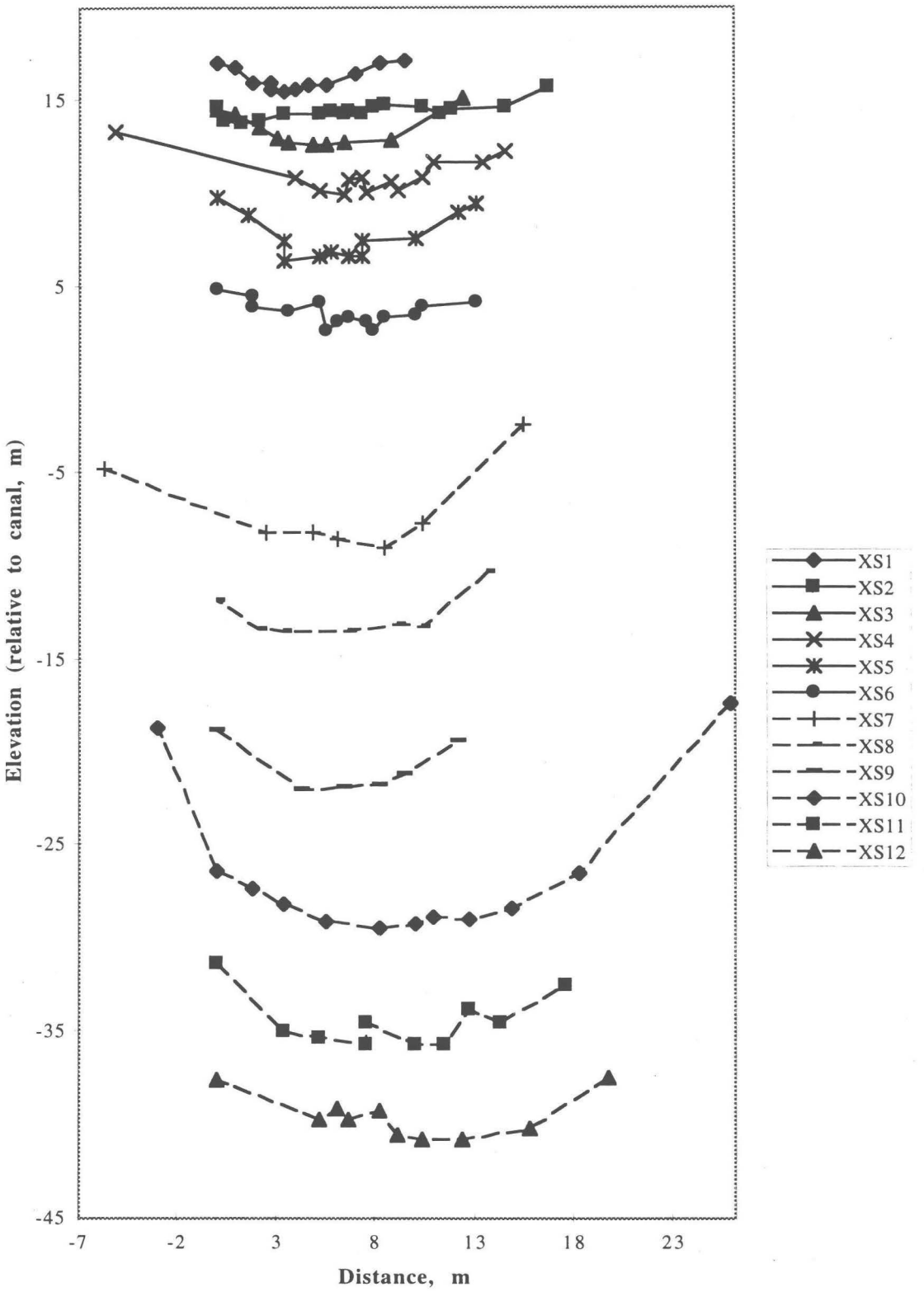

Figure 18. Rucker Creek surveyed cross-sections.

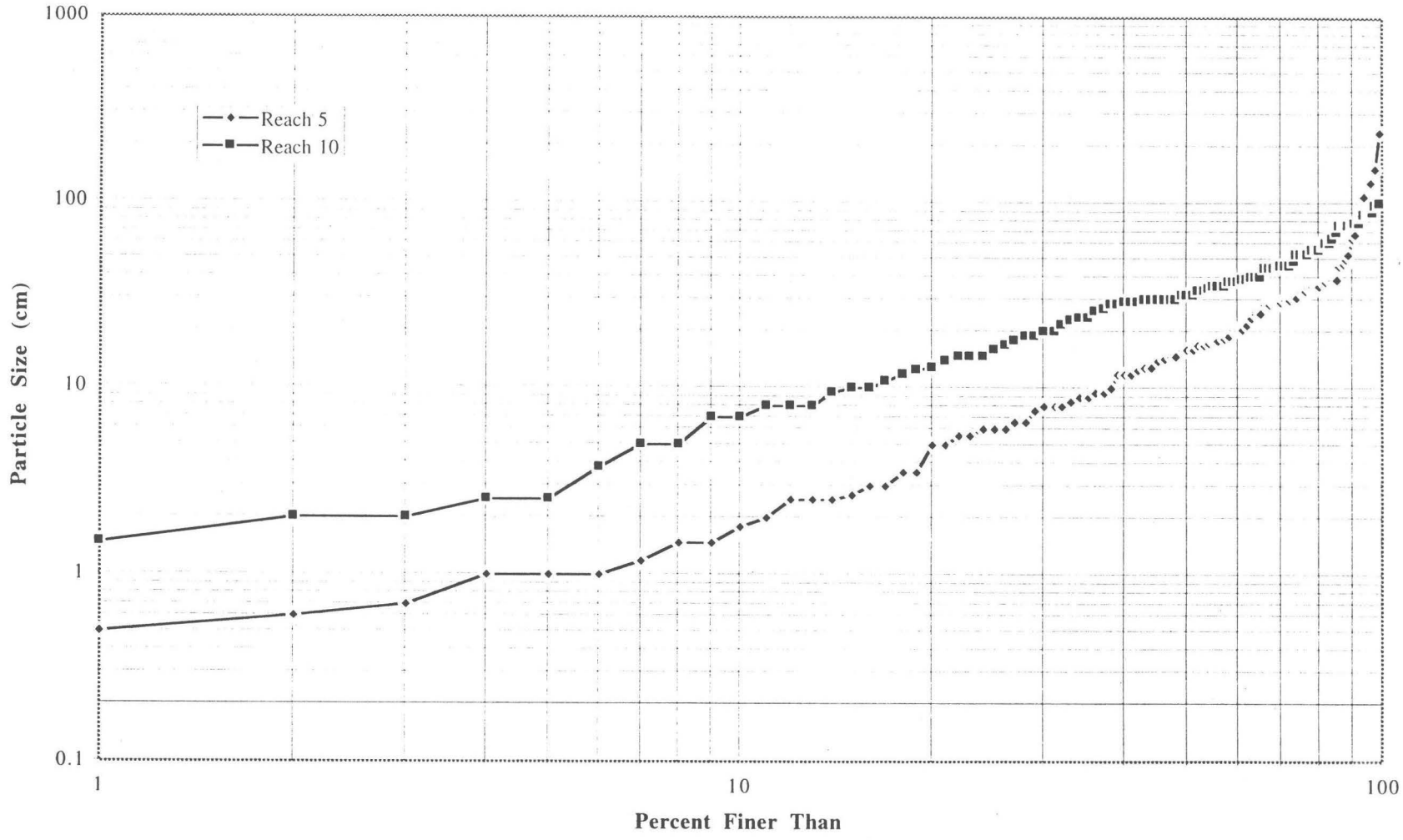

Figure 19. Rucker Creek particle size distribution.

There was one spill gate found that was not constructed to coincide with a stream channel. The spill gate was located approximately half-way between Clear and Fall Creeks along the canal. The gate spilled released water through a pipe over a hillside, which had become excessively eroded as a result (Figure 20). Estimations of the erosion scour were made and the volume calculated (Table 7).

Figure 20. Scoured hillside below canal release gate between Clear and Fall Creeks.

Table 7. Calculation of scour hole volume.

Scour length (m)	Shape of cross-section	Ave. base (m)	Ave. height (m)	Total (m^3)
0-34	triangular	11.5	11.5	2,248
34-68	rectangular	13.0	6.5	2,873
Total (m^3)				5,120

Large Woody Debris

The results for large woody debris volume indices and average number of pieces per reach are given in Table 8. Means and standard deviations were calculated for both measurements over upstream and downstream reaches.

Table 8. Large Woody Debris: Values and standard deviations of volume index (m^3) and average number of pieces per reach.

Stream and Index	upstream	downstream	p-value
Clear, Vol. Index	.40 (.39)	.17 (.26)	<.30
Clear, # of Pieces	5.4 (2.2)	1.2 (1.8)	<.05
Fall, Vol. Index	.09 (.14)	.78 (.89)	<.10
Fall, # of Pieces	1.4 (2.2)	4.2 (1.8)	<.05
Trap, Vol. Index	.26 (.04)	.31 (.06)	<.20
Trap, # of Pieces	8.2 (4.1)	18 (5.9)	<.05

The three streams did not follow a consistent pattern between upstream and downstream reaches for either large woody debris size or number of pieces per reach. In Clear Creek, the volume indices suggested that large woody debris may have been larger in upstream reaches than downstream reaches, but the statistical significance was low (p-value<.30). Pieces were more numerous upstream of the canal on Clear Creek than downstream (p-value<.05). Fall Creek generally had larger pieces downstream of the canal than upstream (p-value<.10), and pieces were more numerous downstream of the canal (p-value<.05). Trap Creek was similar to Fall Creek in that pieces of debris were larger

downstream of the canal than upstream (p-value<.2), and pieces were more numerous downstream of the canal (Figure 21 and 22).

Figure 21. Large woody debris in Trap Creek, upstream of canal.

Figure 22. Large woody debris in Trap Creek, downstream of canal.

Biological

Benthic Samples

A total of 75 insect taxa were collected among the 4 streams between 9 July 1995 and 19 November 1995. All samples were dominated by the order Ephemeroptera (12 genera in 5 families), Plecoptera (22 genera in 6 families), Trichoptera (24 genera in 14 families), and Diptera (8 families), in that order of decreasing predominance.

Habitats were differentiated based on permanence of flow and taxa preferences were identified (Table 9). "Permanent stream" were those with some amount of flow throughout the study period (Clear u/s, Fall u/s, Fall d/s, and Rucker u/s). "Manipulated permanent" streams, a subset of permanent streams, were habitats with permanent, and relatively stable, flow, but due only to flow regulations of the canal or reservoirs (Clear

d/s, and Rucker u/s). "Intermittent" habitats include all other streams sections, those that had some period of no flow during the study (Clear u/s, Trap u/s, Trap d/s, and Rucker d/s).

The majority (55%) of taxa were opportunists, existing in both permanent and intermittent streams. Permanent streams held 32% of taxa, with 31% of those (10% of total taxa) preferring physically stabilized (flow regulated) habitats. Finally, 4% of taxa were found in intermittent habitats only. It is difficult to determine if individuals were endemic to the downstream reaches of Trap and Rucker Creeks, or if they had been washed into the reaches with prior canal releases. No unique taxa to the downstream reach of either Trap or Rucker Creeks were found.

Abundance rating are given in Table 10. The ratings were determined by calculating the interquartile ranges of taxa frequency data. The lower quartile was found to be 1 organism per sample, the upper quartile was 16 individuals per sample. Thus "rare" abundance was defined as one individual per site, "intermediate" abundance as 2 to 15 individuals per site, and "abundant" as 16 or more individuals per site. Four taxa were found at all sites, 6 taxa were in 7 of the 8 sites, and 7 taxa were found in 6 of the 8 sites. Abundances, however, did not necessarily correspond to ubiquity.

The four stream reaches with the most taxa were those with permanent flows. The intermittent, upstream sections of Clear and Trap Creeks had the next highest number of taxa, with the downstream reaches of Trap and Rucker Creeks having the fewest taxa.

Table 9. General habitat preferences of macroinvertebrates found in Clear, Fall, Trap and Rucker Creeks.

Taxon	Permanent Flow Only	"False" Permanent Only Cd/s, Ru/s	Intermittent Only	Generalist (Permanent & Intermittent)
Ephemeroptera				
Baetidae				
Baetis				X
Ephemerellidae				
Caudatella	X			
Drunella				X
Ephemerella				X
Serratella				X
Heptageniidae				
Cinygma				X
Cinygmula				X
Epeorus				X
Ironodes				X
Rhithrogena	X			
Leptophlebiidae				
Paraleptophlebia				X
Siphlonuridae				
Ameletus				X
Plecoptera				
Chloroperlidae				
Alloperla	X			
Kathroperla				X
Plumiperla				X
Suwallia	X			
Sweltsa				X
Leuctridae				
Despaxia	X			
Moselia	X			
Paraleuctra	X			
Nemouridae				
Malenka				X
Soyedina				X
Visoka				X
Zapada				X
Perlidae				
Calineuria				X
Doroneuria				X
Hesperoperla				X

Table 9. Continued

Taxon	Permanent Flow Only	"False Permanent Only Cd/s, Ru/s	Intermittent Only	Generalist, both
Perlodidae				
Isoperla				X
Kogotus			X	
Oroperla	X			
Osobenus	X			
Perlinodes	X			
Rickera	X			
Skwala				X
Trichoptera				
Brachycentridae				
Micrasema	X			
Calamoceratidae				
Heteroplectron				X
Glossosomatidae				
Agapetus				X
Glossosoma	X			
Helicopsychidae				
Helicopsyche	X	X		
Hydropsychidae				
Arctopsyche	X	X		
Ceratopsyche				X
Parapsyche				X
Hydroptilidae				
Ochrotrichia	X			
Lepidostomatidae				
Lepidostoma				X
Limnephilidae				
Apatania				X
Chyranda	X			
Homophylax	X			
Lenarchus	X	X		
Psychoglypha				X
Philopotamidae				
Dolophilodes				X
Wormaldia				X
Phryganeidae (pupa)	X	X		
Polycentropodidae				
Polycentropus				X
Rhyacophilidae				
Rhyacophila				X

Table 9. Continued

Taxon	Permanent Flow Only	"False Permanent Only Cd/s, Ru/s	Intermittent Only	Generalist, both
Sericostomatidae				
Gumaga				X
Uenoidae				
Neophylax			X	
Oligophlebodes	X			
Diptera				
Ceratopogonidae				X
Chironomidae				X
Dixidae				X
Nymphomyiidae	X			
Simuliidae				X
Stratiomyidae				X
Tabanidae	X	X		
Tipulidae				X
Megaloptera				
Corydalidae				
Orohermes				X
Sialidae				
Sialis				X
Coleoptera				
Dytiscidae				
Hydaticus				X
Elmidae				X
Psephenidae				
Eubrianix	X			
Staphylinidae	X			
Tenebrionidae	X	X		
Odonata				
Coenagraionidae				
Argia	X	X		
Gomphidae				
Octogomphus				X
Total Taxa	26	8	3	45

Table 10. Streams in order of taxa abundance, taxa in order of ubiquity (based on benthic sampling). Abundant (A) = greater than 15 frequencity per site, Intermediate (I) = 2 - 15 frequencies per site, Rare (R) = a frequency of 1 collection per site.

Taxon	Fall, d/s	Clear, d/s	Fall, u/s	Rucker, u/s	Clear, u/s	Trap, u/s	Trap, d/s	Rucker, d/s	Total Sites
Paraleptophlebia	A	A	I	A	I	A	R	I	8
Zapada	A	A	A	I	I	I	I	R	8
Tipulidae	A	A	A	A	A	A	R	R	8
Sweltsa	A	A	I	I	R	I	I	I	8
Cinygma	I	I	R	R	I	A	A	I	8
Cinygmula	A	A	A	I	I	A	R		7
Baetis	A	A	A	A	I	A	A		7
Ameletus	A	A	I		A	A	A	I	7
Lepidostoma	I	A	I	I	R	I	I		7
Malenka	I	I	I	I	I	I	I		7
Plumiperla	I	I	R		I	I	I	R	7
Serratella	I	A	A	A	I	R			6
Chironomidae	A	A	A	A	I	I			6
Rhyacophila	A	A	A	A	I	I			6
Ironodes	I	I	I	A		I	I		6
Epeorus	R		I	I	R	I		R	6
Elmidae	R	R	I	I	I			R	6
Hydaticus	I	R		R	R	R	I		6
Calineuria	A	A	A	A	I				5
Drunella	I	A	A		I	I			5
Ceratopsyche	A	I	A	A			I		5
Orohermes	I	I	I	A	I				5
Gumaga	I	I	I	I			R		5
Polycentropus	I	I		R	R		I		5
Parapsyche			I	R	R	I	I		5
Simuliidae		A	I	R	R				4
Agapetus	I	I	A			R			4
Stratiomyidae	I		I		I	I			4
Doroneuria	I		I	I		R			4
Ochrotrichia	I	I	R	R					4
Ephemerella	R	I	I				R		4
Wormaldia		R	I	I		I			4
Ceratopogonidae	R	I		I	R				4
Kathroperla	R	R	I		I				4
Osobenus	I	A		R					3
Visoka	A		I			I			3
Isoperla			R			A	R		3
Hesperoperla		I		A				R	3
Octogomphus		I		A				R	3
Suwallia	I	I	I						3
Dolophilodes	R					I	I		3
Apatania	I			R	R				3
Neophylax					R	R	I		3
Psychoglypha	R				R			I	3
Rhithrogena	I		A						2
Perlinodes	I	A							2
Eubrianix	R			I					2
Skwala	R				I				2
Micrasema	I		R						2
Soyedina		I					R		2
Heteroplectron				I			R		2
Oroperla	R		I						2

Table 10. Continued.

Dixidae		R				I			2
Sialis		I				R			2
Helicopsyche				I					1
Caudatella			I						1
Paraleuctra	I								1
Despaxia	I								1
Tenebrionidae		I							1
Argia				I					1
Alloperla	R								1
Kogotus						R			1
Moselia			R						1
Rickera	R								1
Glossosoma	R								1
Arctpsyche		R							1
Chyranda		R							1
Homophylax	R								1
Lenarchus		R							1
Oligophlebodes			R						1
Phryganeidae		R							1
Nymphomyiidae	R								1
Tabanidae				R					1
Staphylinidae	R								1
Total Taxa	51	43	40	37	30	30	24	12	

Biotic indices, taxa richness, Shannon diversity, Shannon evenness, and numbers of individuals per sample were compared between upstream and downstream reaches on all streams (Figures 23 through 26). Differences between upstream and downstream values of these indices were calculated and evaluated for temporal trends over the study period (Figure 27). These indices do not follow consistent trends according to upstream vs. downstream site location. The downstream reach on Clear Creek shows consistent increases in biotic indices over time, Fall and Trap Creeks remain fairly constant, while Rucker Creek decreases in all indices downstream.

Multiple regression was used to correlate physical parameters with biotic indices. In all cases, the duration of flow during the study period, "Percent Flow", was the only significant factor correlated with all biotic indices. Further, the most correlation between physical parameters and biotic indices resulted from single regression using Percent Flow only, with some data sets having higher correlation after being transformed by the natural logarithm. Table 11 summarizes the relative importance of the physical parameters. The

partial F and probability values of the multiple regressions are given, while Figures 28 through 31 show the results of regression using Percent Flow only.

Table 11. Partial F and probability values from multiple regression with all physical parameters.

	% Flow		d50		Slope		High Temp.		ln(mean vel.)	
Biotic Index	F	p	F	p	F	p	F	p	F	p
ln(Richness)	28.8	.03	3.8	.19	2.2	.28	.1	.83	.7	.49
ln(Diversity)	25	.04	1.6	.33	2.3	.27	8.1	.10	2.6	.25
Evenness	5.4	.15	8.4	.10	5.0	.15	3.7	.19	4.7	.16
ln(#Indiv.)	10.7	.08	4.9	.16	3.6	.20	.3	.62	1.4	.36

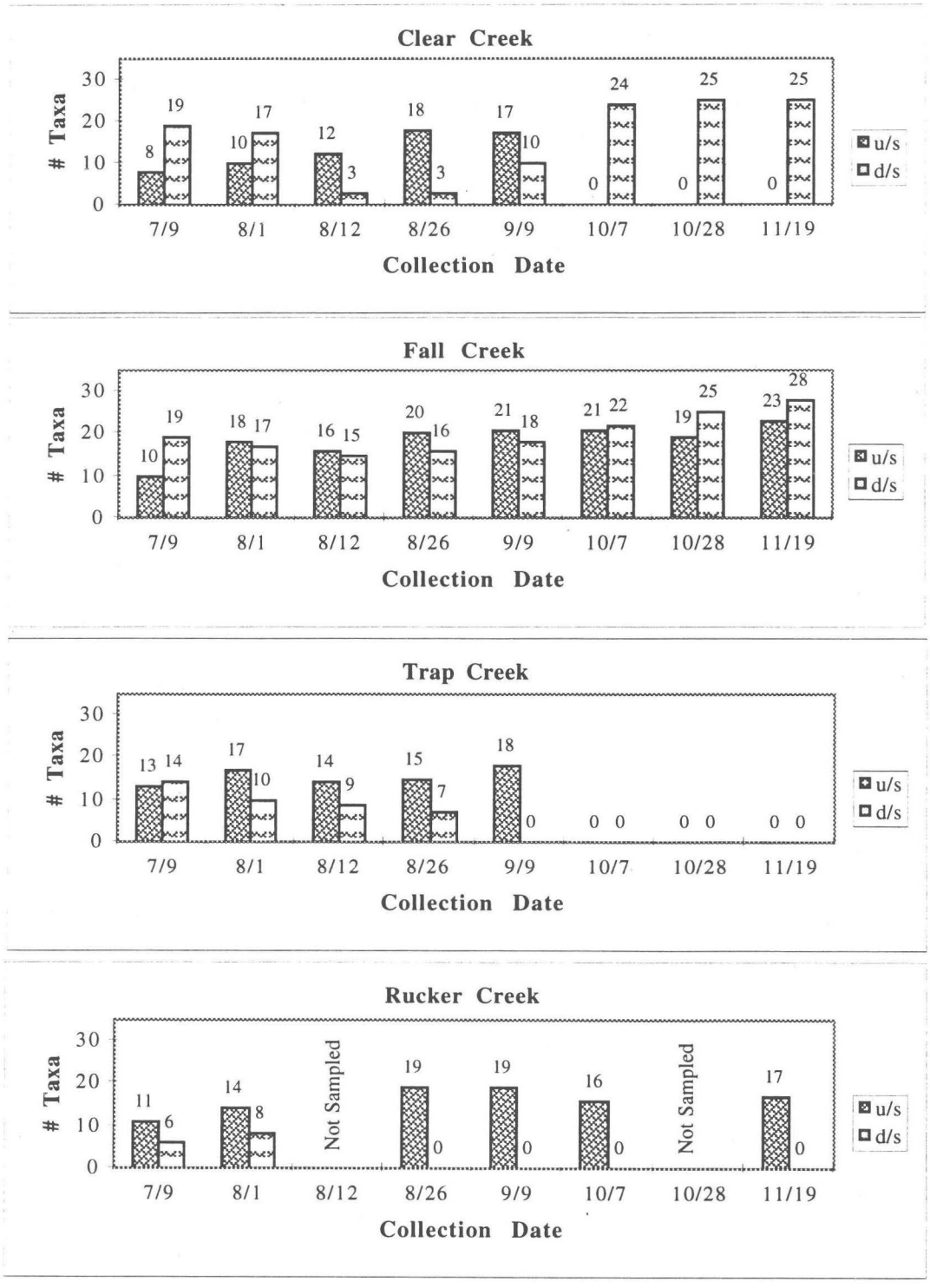

Figure 23. Taxa richness among streams.

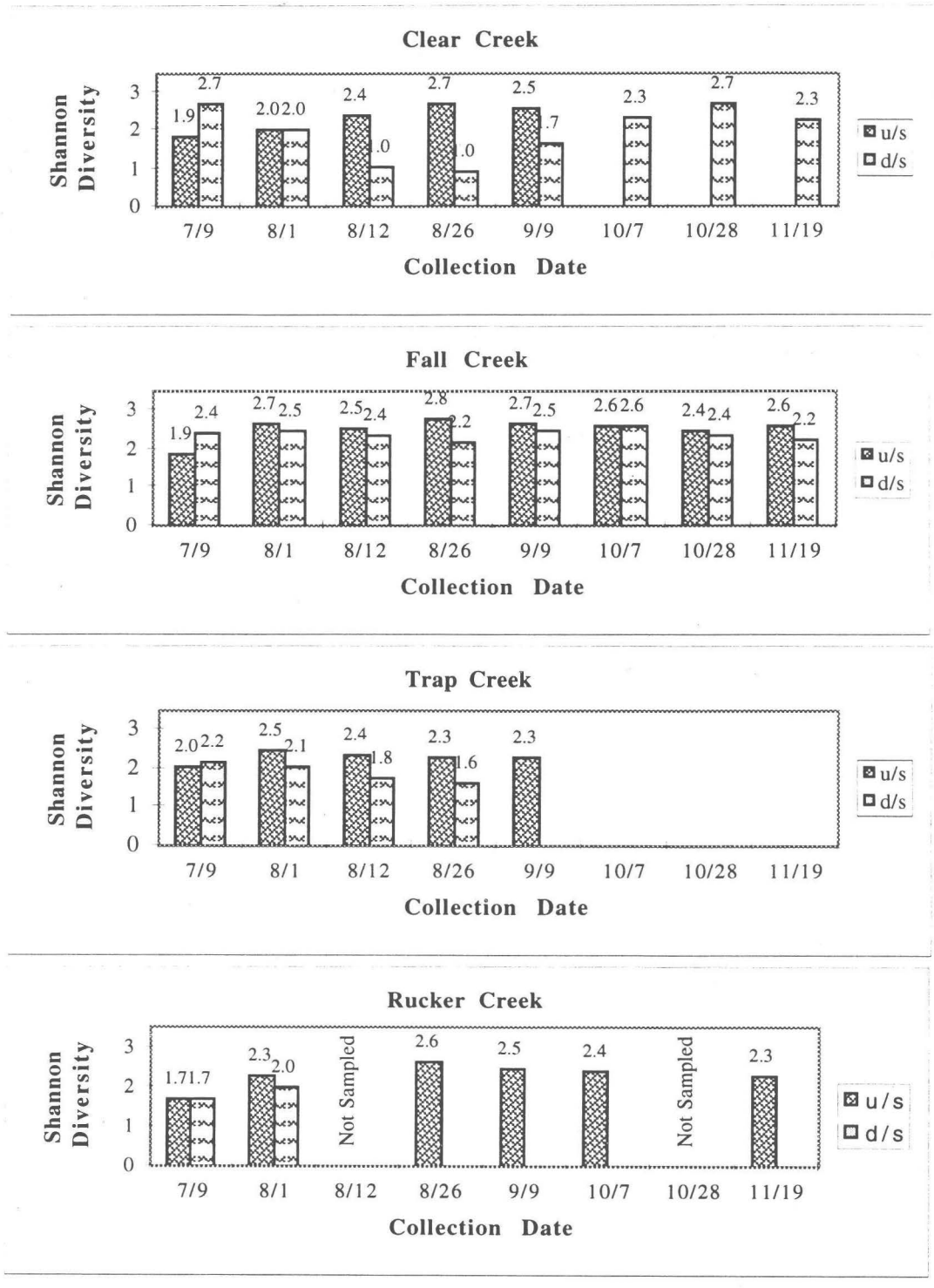

Figure 24. Shannon diversity among streams.

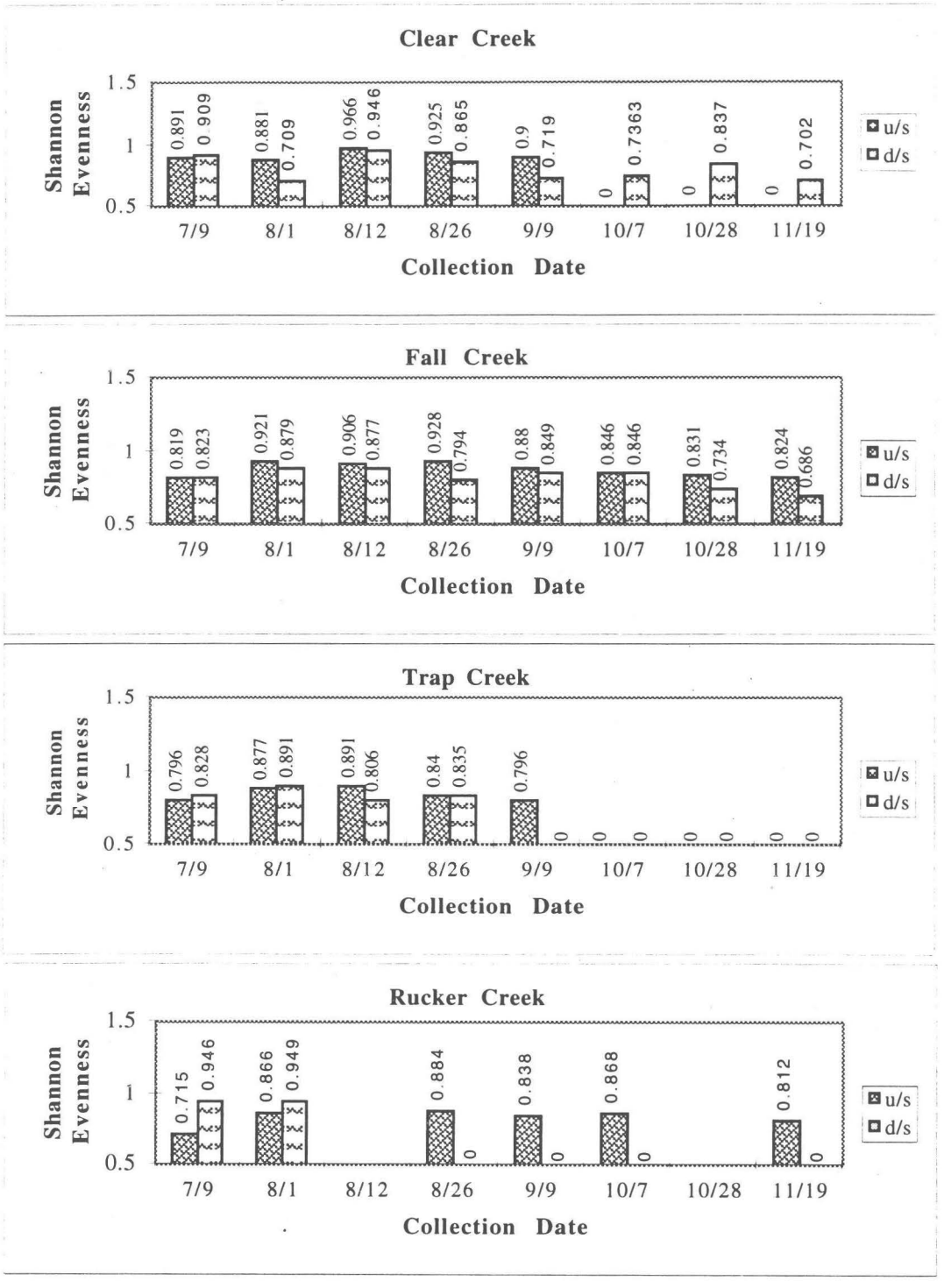

Figure 25. Shannon evenness among streams.

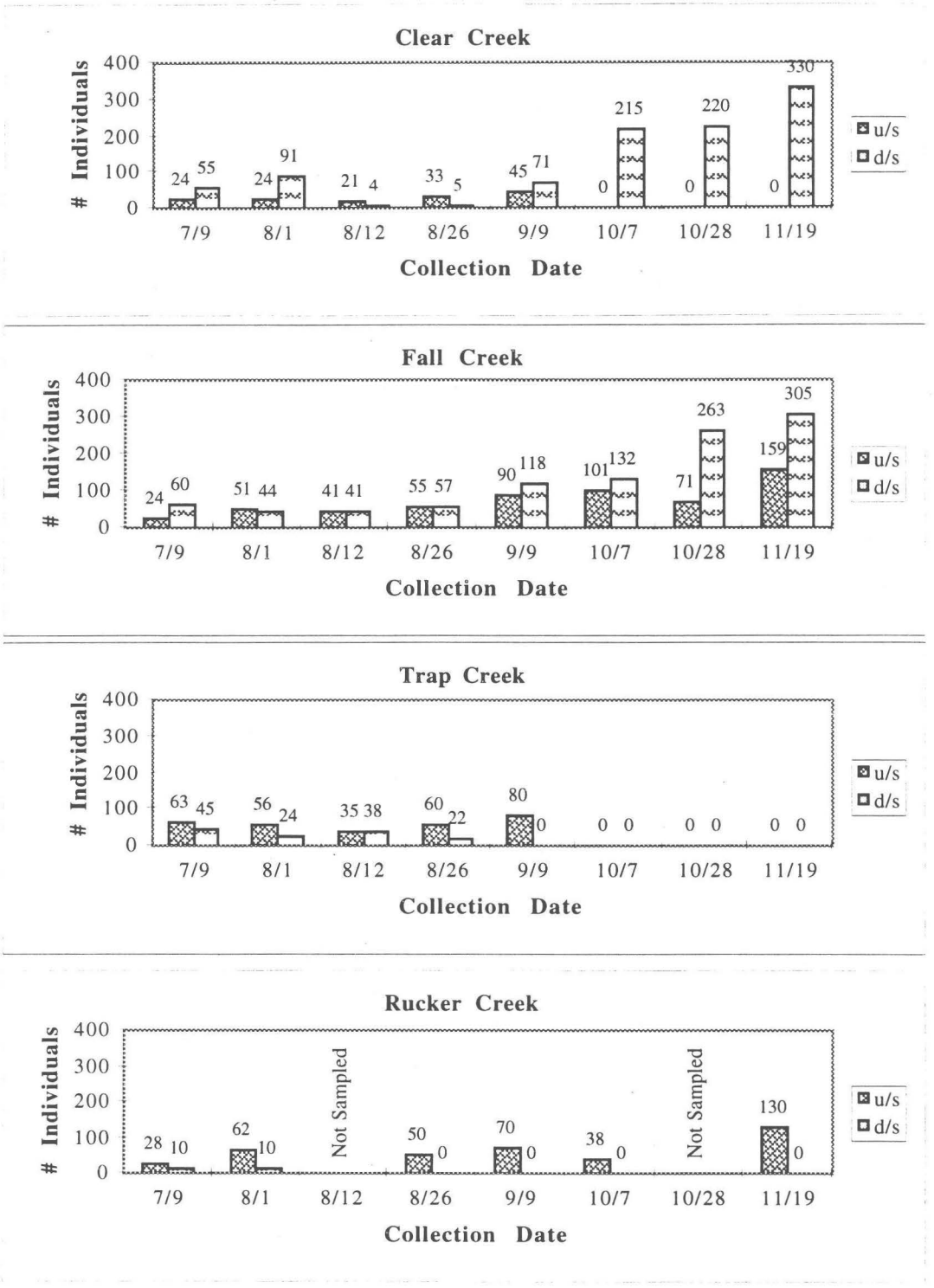

Figure 26. Number of individuals per sample among streams.

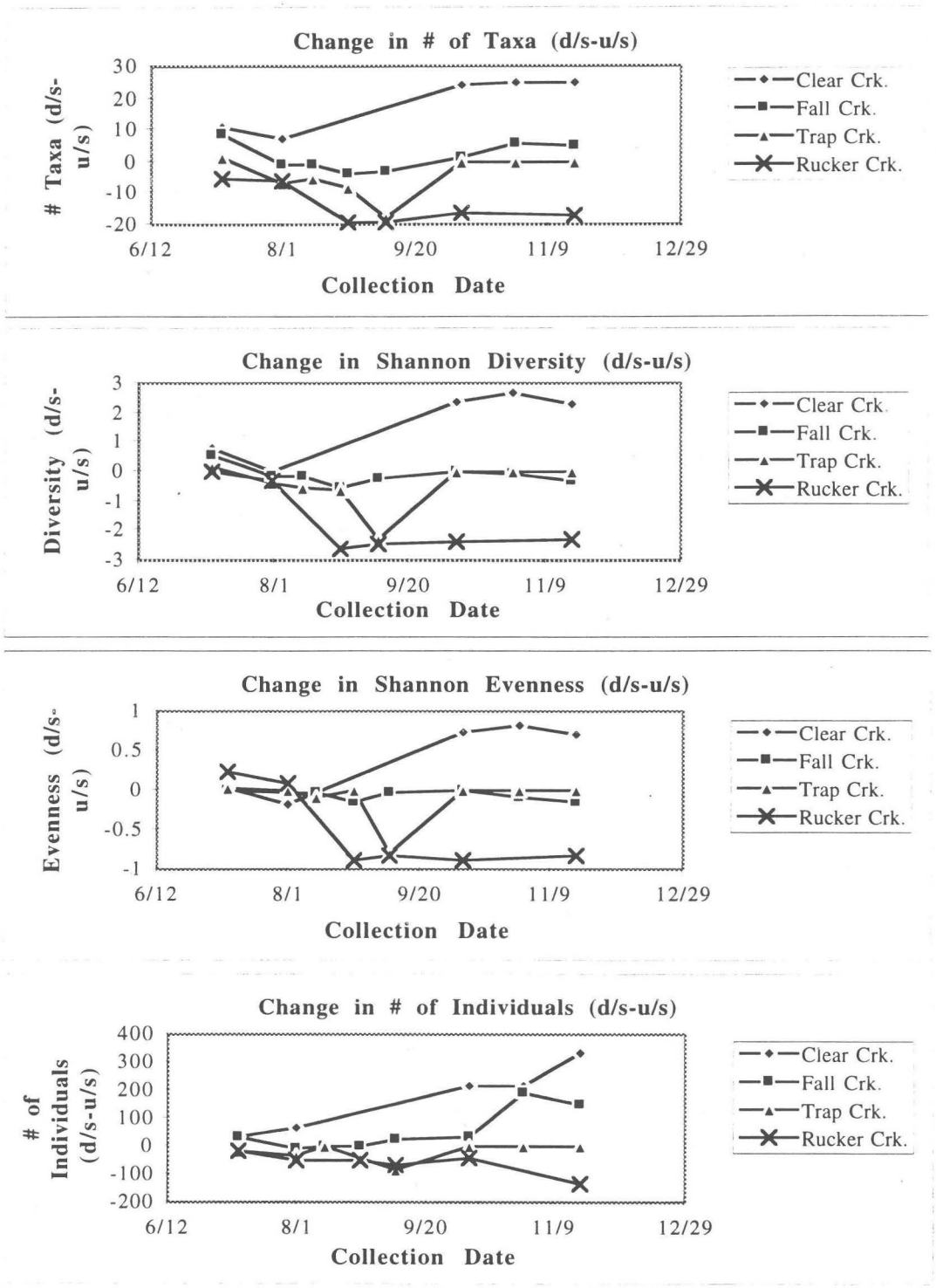

Figure 27. Differences between upstream and downstream indices over the study period.

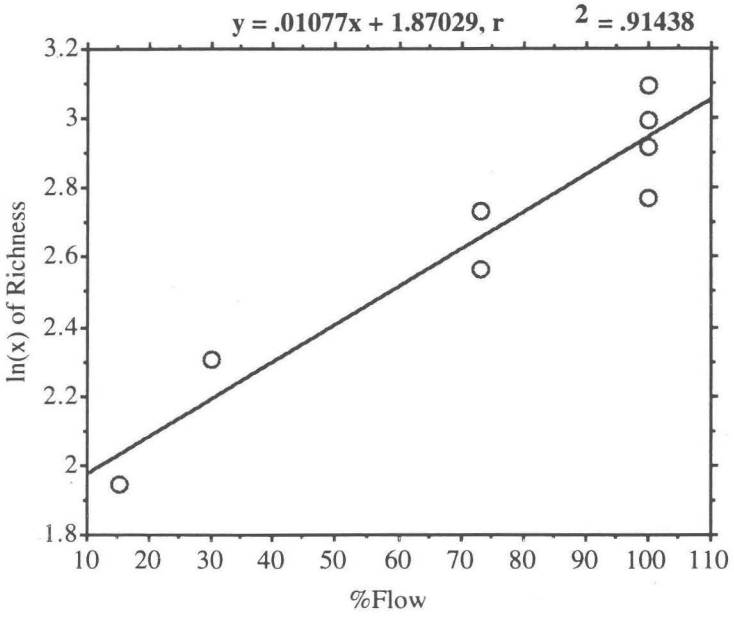

Figure 28. Correlation between taxa richness and percent time of flow.

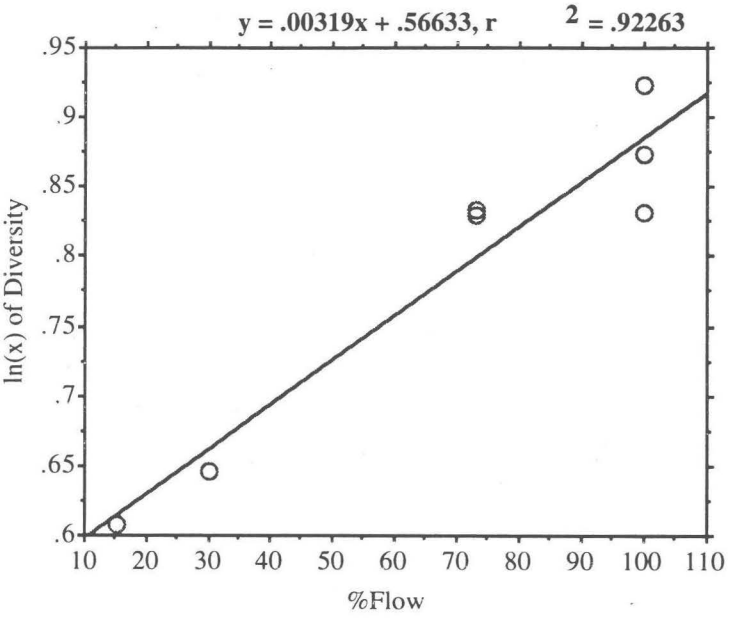

Figure 29. Correlation between ln of Shannon Diversity and percent time of flow.

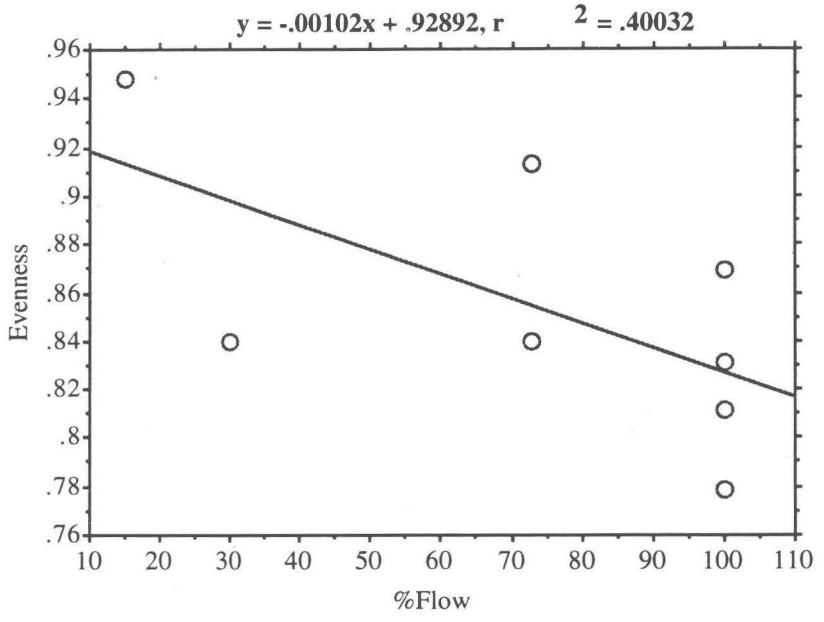

Figure 30. Correlation between ln of Shannon Evenness and percent time of flow.

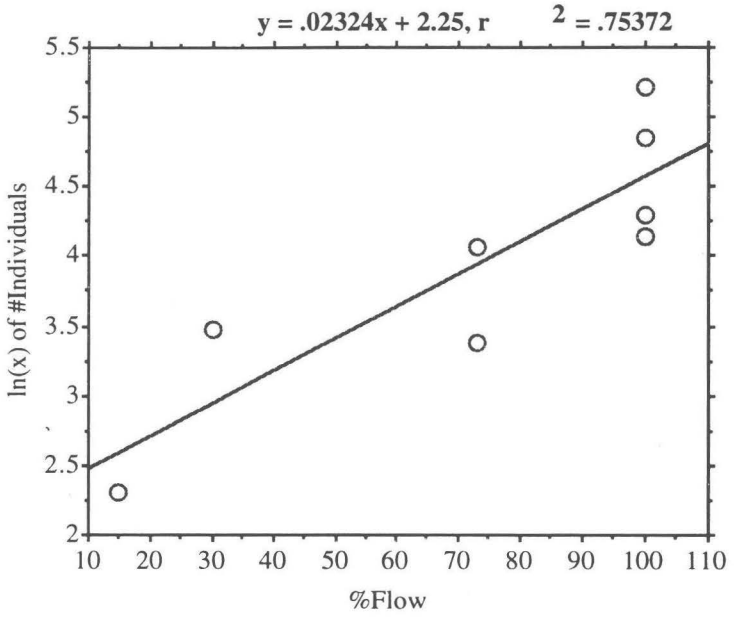

Figure 31. Correlation between numbers of individuals (ln) and percent time of flow.

The similarity analysis, using all taxa found over the entire study period, is summarized in Table 12. The results show that stream sections are not necessarily more

similar within streams, than among streams. The stream sections with the least amount of continuous flow downstream of the canal, Trap and Rucker Creeks, were the least similar to other study stream sections. Comparisons of sites that contained flow throughout the study period (Clear d/s, Fall u/s, Fall d/s, and Rucker u/s) were all above the overall average similarity index of 0.395. Thus, not only do these sites have higher taxa richness, but are also more similar in the taxa they contain than are many of the other combinations. Several other similarity comparisons among all stream sites showed higher than average similarity, yet only one comparison with a highly impacted stream reach showed a higher than average similarity (Trap Creek upstream and downstream). The two highly impacted stream reaches, Trap and Rucker Creeks downstream of the canal, had almost all comparisons below the average similarity. Trap Creek, downstream had one comparison higher than average (Trap downstream vs. Trap upstream). Rucker Creek, downstream had no comparisons above the overall average similarity.

Table 12. Results of taxa similarity comparisons among streams. Average = .395.

	Clear u/s	Clear d/s	Fall u/s	Fall d/s	Trap u/s	Trap d/s	Rucker u/s	Rucker d/s	Average
Clear, u/s		0.460	0.489	0.500	0.513	0.385	0.522	0.313	0.453
Clear, d/s			0.491	0.508	0.404	0.354	0.538	0.227	0.426
Fall, u/s				0.570	0.500	0.370	0.462	0.227	0.444
Fall, d/s					0.390	0.321	0.450	0.189	0.419
Trap, u/s						0.459	0.375	0.212	0.407
Trap, d/s							0.372	0.241	0.356
Rucker, u/s								0.231	0.421
Rucker, d/s									0.234

Alternative Sampling Methods

The sampling method results are presented in Table 13. These data are for the major aquatic orders and are taken for the entire sampling period. The benthic samples had a consistent and distinct predominance of ephemeropterans, plecopterans, trichopterans,

and dipterans in that respective order of decreasing relative abundance. The emergence traps had a strong predominance of dipterans, with relatively minor numbers of other orders in most samples (Appendix D). The artificial substrate (brick) samples were colonized by few individuals, and few taxa (Appendix C). Most bricks were absent of any individuals.

Table 13. Relative abundance (%) of orders among sampling methods, with averages and standard deviations.

Sample Method	Sample Site								
	Clear u/s	Clear d/s	Fall u/s	Fall d/s	Trap u/s	Trap d/s	Rucker u/s	Rucker d/s	Ave. (s.d.)
Benthic									
Ephem.	46	55	51	54	57	65	43	55	53.4 (6.8)
Plecop.	23	25	28	28	27	20	30	24	25.6 (3.2)
Trichop.	16	13	16	11	10	14	16	9	13.1 (2.9)
Diptera	13	7	5	6	6	1	4	3	5.6 (3.5)
Brick									
Ephem.	15	14	11	4	50	25	25		20.6 (15.0)
Plecop.	11	10	1	3	10	0	13		6.9 (5.3)
Trichop.	9	55	17	32	20	25	38		28.0 (15.3)
Diptera	66	21	4	61	20	50	25		35.3 (23.6)
Emergence Trap									
Ephem.			4	2	0	1			1.8 (1.7)
Plecop.			9	10	4	4			6.8 (3.2)
Trichop.			10	3	2	1			4.0 (4.1)
Diptera			77	85	94	94			87.5 (8.2)

DISCUSSION

Physical

The Bowman-Spaulding Canal has had impacts on sediment transport and storage in all study streams. Bedload deposition has occurred upstream of the canal, while the stream channels have been incised directly below the canal. Downstream channel erosion has been caused by both the lack of a bedload transport from upstream, and releases of canal waters that are clean and high energy. This difference in sediment dynamics results in a generally larger substrate particle size distribution downstream of the canal. Clear Creek is an exception to this, due to the sloughing of the road and channels banks, which are composed of decomposed, finer, granite sediments.

Water released from the canal has also caused severe erosion on at least one hillslope area below the canal. The spill gate between Fall and Clear Creeks, used for canal water flow regulation, has scoured more than 5,000 m^3 of sediment from the hillslope (which has no associated drainage channel upstream of the canal). The sediment load from the hillslope has been (and continues to be) flushed into Clear and Fall Creeks which feed into the South Fork Yuba River, and all support native trout fisheries.

The large woody debris analysis did not reveal a consistent pattern of debris distribution over the three streams in which it was measured (Clear, Fall, and Trap Creeks).The differences may have been due to past land-use practices (logging) and effects that the canal may have had on large woody debris load and storage in streams. The number of debris pieces was significantly different between upstream and downstream reaches on Clear, Fall and Trap Creeks. Clear Creek had more debris pieces upstream of the canal than downstream, while Fall and Trap Creeks had more debris pieces downstream of the canal. Clear Creek also differed in having larger pieces upstream of the canal than

downstream, while Fall and Trap Creeks had larger pieces of debris downstream of the canal.

All three watersheds had evidence of past logging, though Clear Creek downstream of the canal, had noticeably greater and more recent evidence of logging. Nearby hillsides were denuded of trees from a clear-cut, a bare landing area still existed adjacent to the downstream study area, and the riparian corridor held few large trees. Portions of the watershed upstream of the canal also had evidence of recent logging, but not to the degree of the downstream watershed, nor was there much evidence of recent logging near the stream. Bilby and Ward (1991) have shown that large woody debris abundance and size decreased with time between clear-cut and second growth forests. Residual wood in the channel decomposes with time, while the input of debris from riparian zones decreases due to the lack of source wood. This would provide a consistent explanation for the difference in debris composition between the upstream and downstream reaches of Clear Creek. Residual wood in the channel downstream of the canal may have been removed right after the logging occurred, or it could have decomposed, or both. The amount of coniferous trees in, or adjacent to the riparian zone downstream of the canal on Clear Creek had not been abundant or old enough to begin the process of loading the stream channel with falling large debris.

Fall and Trap Creeks had debris distributions as might be expected with the canal intercepting the creeks. These streams lack the continuum of flow and transport of debris from reaches upstream of the canal to reaches downstream of the canal. Some debris may be able to go over the check dam on Fall Creek during high flows and continue on to the downstream reaches. But generally, canal maintenance crew remove all debris backed up by the check dam. A piece of debris, approximately five meters long was observed on the Fall Creek check dam in May, 1995. By June 1995, the debris had been sawed into small pieces by canal operators and left downstream of the canal. It has been observed that

frequency of pieces decreases and size of debris pieces increases as stream width increases (Bilby and Ward 1989). This phenomenon is due to the streams increasing ability to move large woody debris as flow increases downstream. The headwater will thus have more pieces, and of varying sizes, while downstream reaches will have only the fewer, larger pieces left in the channel. This could explain the larger debris pieces downstream of the canal on Fall Creek, but not the higher number of pieces downstream. The upstream study area may have had a decreased number of debris pieces due to the higher degree of channel constraint upstream of the canal than downstream of the canal. Constrained reaches, in which the valley floor is narrower, generally have straight channels with higher stream power during spates (Sedell et al. 1990). A higher stream power upstream of the canal on Fall Creek would flush more debris from the channel than the less constrained flow downstream of the canal.

The higher number and size of debris in the downstream study reaches of Trap Creek can be explained by the accelerated erosion and sloughing of stream banks with associated terrestrial vegetation downstream of the canal. Trap Creek, downstream of the canal, was characterized as having the most numerous (8.2 pieces per reach) and largest (18 m^3 per piece) woody debris of the three streams measured. The debris in Trap Creek downstream of the canal, however, does not function adequately for habitat diversification, or sediment and organic debris storage because of the lack of water during a majority of the time.

Biological

Comparison of Sampling Techniques

This study incorporated the three sampling techniques of benthic, emergence trap, and artificial substrate sampling. Though the use of artificial substrates has been used successfully in other macroinvertebrate studies (Lamberti and Resh 1983, Rosenberg and Resh 1982), the technique was not as successful in this study. The high variability among brick samples and the high degree of uncolonized bricks provided too much inconsistency and too little data to be of use in evaluating stream communities and effects of the canal. Emergence traps were placed on Fall and Trap Creeks, above and below the canal. Sampling adult aquatic insects allows for the identification of the organisms to species, which has great value in ecological studies. Though some generalizations of habitat preferences and life histories can be made at the genus level, a much more precise level of ecological evaluation can be made when using a species level taxon. The species level is also crucial for the identification of rare and endemic species. Emergence traps may also collect more species from a site than benthic samples (Erman and Erman 1990). Emergence trap data collected for this project have been used at the order level thus far. A continuation of data analysis will provide data at the species level for further evaluation of the study streams at a later date. The vast majority of data used for this evaluation has been from the benthic sampling.

Though one may hope to collect a representative sample of the community with any sampling method, each method has its own bias in organisms sampled (Rosenberg and Resh 1982, Merritt and Cummins 1996). The benthic and emergence trap samples of this study obtained much different data from similar sites based on data at the order level. Benthic samples may miss taxa which reside deep in the hyporheic zone (McElravy and

Resh 1991), while emergence traps may be biased in collecting individuals of certain orders (Diptera, Trichoptera, and Plecoptera) more efficiently than others (Ephemeroptera). Emergence trap sampling also collects more terrestrial or semi-aquatic species because of the spatial gap between the trap bottom and the water surface.

Comparison of Taxa

Taxa collected from the upstream reach of Clear Creek but not the downstream reach were *Epeorus* sp., Parapsyche sp., *Gumaga* sp., *Stratiomyidae* sp., *Apatania* sp. and *Neophylax* sp. These taxa have species that are fairly adaptable to a variety of lotic habitats, with *Epeorus* sp., *Parapsyche* sp., Stratiomyidae, and *Neophylax* sp. able to persist in intermittent streams (Abell 1956, Gilpin and Brown 1970, Anderson and Dietrich 1992). Their absence from the downstream reach may have been due to a preferred intermittent habitat, an inability to compete in the downstream reach, which had more taxa residing in it, or random sampling error (none of these taxa were abundant in the upstream reach). Taxa in the downstream reach absent from the upstream reach were *Ironodes* sp., *Ceratopsyche* sp., *Gumaga* sp., *Agapetus* sp., *Ochrotrichia* sp., *Suwallia* sp., *Perlinodes* sp., *Soyedina* sp., Dixidae, *Sialis* sp., Tenebrionidae, *Arctopsyche* sp., *Chyranda* sp., *Lenarchus* sp., and Phrynganeidae. Only two of these taxa were abundant in the downstream reach, *Osobenus* sp. and *Perlinodes* sp. Relatively little is known about the species in the genus *Osobenus* sp. (Stewart and Stark 1988). In this study, it occurred in intermediate amounts in the downstream reach of Fall Creek, abundantly in the downstream reach of Clear Creek, and rarely in the upstream reach of Rucker Creek. These reaches were the only sections among the study streams that had fairly consistent and persistent base flows throughout the summer and fall. *Osobenus* sp. may have habitat preferences for such permanent, consistent flow in its habitat requirements. *Perlinodes* sp. is another perlodid taxa on which few studies have been conducted (Stewart and Stark 1993). Sheldon (1972) found it in rare numbers in Sagehen Creek, with increasing numbers

further downstream. Among the streams in this study, *Perlinodes* sp. may also have preferred the habitats containing persistent and consistent base flows. The remaining taxa found in the downstream reach but absent in the upstream reach had adaptable habitat requirements (Abell 1956, Wiggins 1977, Stewart and Stark 1988, Merritt and Cummins 1996). These adaptabilities may have enabled the taxa to partition the downstream resources, allowing more taxa to survive in the permanent flow reach than the intermittent upstream reach.

The upstream and downstream reach of Fall Creek were the most similar reaches among the study streams. Taxa found in the upstream reach but absent in the downstream reach were *Parapsyche* sp., Simuliidae, *Wormaldia* sp., *Isoperla* sp., *Caudatella* sp., *Moselia* sp., and *Oligophlebodes* sp. Species of Simuliidae and *Caudatella* sp. are adapted to various lotic habitats; and *Parapsyche* sp., *Wormaldia* sp., *Isoperla* sp., *Moselia* sp. and *Oligophlebodes* sp. have been reported in headwater streams and springs (Wiggins 1977, Erman and Erman 1990, Stewart and Stark 1988, Merritt and Cummins 1996). None of the taxa were abundant in the upstream reach and their absence downstream may be a result of random sampling error versus a habitat preference between the two reaches. Taxa found in the downstream but not upstream reach were *Hydaticus* sp., *Polycentropus* sp., Ceratopogonidae, *Osobenus* sp., *Dolophilodes* sp., *Apatania* sp., *Psychoglypha* sp., *Perlinodes* sp., *Eubrianox* sp. , *Skwala* sp., *Paraleuctra* sp., *Despaxia* sp., *Alloperla* sp., *Rickera* sp., *Glossossoma* sp., *Homophylax* sp., and Staphylinidae. Almost all of these taxa are characterized as having species fairly adaptable to both permanent and temporary habitats, while *Perlinodes* sp. and *Glossosoma* sp. are more limited to permanent streams (Wiggins 1977, Mackay and Wiggins 1979, Stewart and Stark 1988). *Osobenus* sp., *Paraleuctra* sp., *Despaxia* sp., and *Rickera* sp. are taxa that are not understood well at this point (Stewart and Stark 1988). Reasons for differences in taxa between the upstream and downstream reaches are unknown but may be due to sampling as well as to other causes.

Both had permanent flow during the study period, with a continuum of flow and macroinvertebrate transport from upstream to downstream during at least part of the year.

The upstream and downstream reaches of Trap Creek both contain the eleven most common taxa among sites (*Paraleptophlebia* sp., *Zapada* sp., Tipulidae, *Sweltsa* sp., *Cinygma* sp., *Cinygmula* sp., *Baetis* sp., *Ameletus* sp., *Lepidostoma* sp., *Malenka* sp., and *Plumiperla* sp.). However, this similarity may be due more to the high adaptability among these taxa rather than the reaches having similar habitats. The extreme nature of flow increases and decreases into the downstream reach of Trap Creek, with the additional stress of long dry periods, makes the likelihood of a persistent fauna unlikely. Individuals collected in the reach were probably transported with canal water in the spring or may have been nymphs from eggs lain by adults from other water sources. The majority (60%) of individuals collected from the upstream reach of Trap Creek were of taxa adapted to a wide variety of lotic systems (*Baetis* sp., *Ameletus* sp., *Cinygmula* sp., Tipulidae, *Paraleptophlebia* sp., *Cinygma* sp., *Sweltsa* sp., Chironomidae, Stratiomyidae, *Rhyacophila* sp., Dixidae, *Serratella* sp., and *Sialis* sp.)(Merritt and Cummins 1996). Seventy two percent of the taxa contain species that have mechanisms to tolerate intermittency (*Isoperla* sp., *Baetis* sp., *Ameletus* sp., Tipulidae sp., *Parleptophlebia* sp., *Ironodes* sp., *Sweltsa* sp., Chironomidae, Stratiomyidae, *Rhyacophila* sp., *Parapsyche* sp., *Lepidostoma* sp., *Epeorus* sp., *Dolophilodes* sp., *Wormaldia* sp., and *Agapetus* sp.) (Abell 1956, Wiggins et al. 1980, Anderson and Dietrich 1992, Erman and Erman 1990). Since Trap Creek routinely goes dry by the fall months, all persistent taxa would have to tolerate intermittency. This disparity may be due to misclassification of taxa as to their tolerance to intermittency, a yet unknown ability of a species within a genus to tolerate intermittent flow, or taxa may have been introduced into the upstream reach that were not persistent over more than one generation. Twenty two percent of taxa were characterized as having adaptations for high velocities (*Cinygmula* sp., *Cinygma* sp., *Ironodes* sp.,

Drunella sp., *Rhyacophila* sp., *Parapsyche* sp., and *Epeorus* sp.) (Nielsen 1950, Minshall and Minshall 1977). Approximately 9% of taxa are characterized as having species with a preference for cold streams (*Visoka* sp., *Rhyacophila* sp., *Parapsyche* sp., *Lepidostoma* sp., *Zapada* sp., and *Heteroplectron* sp.) (Kerst and Anderson 1975, Wiggins 1977, Stewart and Stark 1988). The fauna of the upstream reach of Trap Creek can be characterized as having opportunistic, adaptive taxa capable of withstanding intermittency, and several taxa which prefer cool, mountain headwater streams.

The upstream and downstream reaches of Rucker Creek were very dissimilar in the taxa collected. As in the downstream reach of Trap Creek, the downstream reach of Rucker Creek probably lacks a persistent macroinvertebrate fauna. Organisms are probably washed in with canal spills or females may lay eggs which hatch in the isolated pools lasting only a few months into the spring. All of the abundant taxa in the upstream reach of Rucker Creek were characterized as having wide habitat tolerances within lotic systems. There were also taxa abundant in the upstream reach of Rucker Creek that were not abundant in other study reaches (*Orohermes* sp., *Hesperoperla* sp. and *Octogomphus* sp.). Taxa found only in the upstream reach were in intermediate amounts (*Helicopsyche* sp. and *Argia* sp.), and a rare occurrence of Tabanidae. These abundant and unique taxa are characterized as occurring in depositional zones of lotic systems and with the exception of *Helicopsyche* sp., are predators (Abell 1956, Mackay and Wiggins 1979, Merritt and Cummins 1996). Rucker, upstream of the canal was unusual among the study streams in having a fauna not indicative of a headwater, mountain stream, but rather a permanent, warmer, more productive, and lower elevational river. This system was due to the consistent release of warm water, high in organic matter (personal observation) from Rucker Lake.

Comparisons of Community Indices

Benthic communities did not show consistent trends between upstream and downstream reaches among streams. Rather, communities showed more consistent trends among stream habitats based on continuity of flow. The stream reaches that had flow throughout the study period, Clear d/s, Fall u/s, Fall d/s, and Rucker u/s, had higher taxa richness, higher Shannon diversity and greater numbers of individuals per sample than stream reaches with intermittent flow, Clear u/s, Trap u/s, Trap d/s, and Rucker d/s. The relationship to Shannon evenness was nearly the inverse, Rucker u/s, Fall d/s, and Clear d/s had the lowest evenness indices, with Fall u/s scoring the third highest. A maximum evenness occurs when all species are equally abundant. These three reaches also had the most stable environments, especially Clear d/s and Rucker u/s, and they had high diversity values. This implies that there was a high diversity of organisms in these stable reaches, but the relative abundance of organisms was not spread evenly.

Most stream reaches with a temporal continuum of flow were also more similar among each other than between the respective upstream and downstream reaches. Fall Creek was the only stream that had a higher similarity between the upstream and downstream reaches than similarity with other permanently flowing stream reaches. However, this is consistent with the inter-habitat similarity trend, since both reaches of Fall Creek had flow throughout the study period. The multiple regression analysis supports this finding of community similarity based on similarity of physical habitat. These findings are also consistent with Angradi (1996), who found that inter-habitat variation exceeded inter-stream variation based on aquatic macroinvertebrate abundance, biomass, functional organization, and taxonomic composition.

Community compositions were dominated (55%) by opportunistic taxa, those that inhabited both permanent and temporary streams. This finding of facultative or generalist

taxa predominance is consistent with several other studies conducted on temporary stream communities (Knight and Gaufin, 1967; Delucchi and Pecharsky, 1989). Though most taxa were opportunists in this study, 32% were found in permanently flowing streams only. Within this group, seven taxa, *Helicopsyche* sp., Tenebrionidae, *Argia* sp., *Arctopsyche* sp., *Chyranda* sp., *Lenarchus* sp., and Phryganeidae were found only in the artificially permanent stream section of Clear, downstream of the canal, or in Rucker, upstream of the canal. If these taxa are dependent upon permanent flow, it is unlikely that they could have lived in either of these streams before the canal and reservoirs were built on the streams. *Arctopsyche* sp., *Chyranda* sp., and Phryganeidae were rare, each with only one individual collected. With a more intensive sampling regime, more individuals of these taxa may have been found in other streams. Samples of *Helicopsyche* sp., Tenebrionidae, and *Argia* sp. were composed of 3 to 8 individuals each; common enough to assume that if they had been present in other reaches, they would have been sampled. If these macroinvertebrates are dependent upon constant stream flow, they may have immigrated to these permanent streams from the South Fork Yuba, or nearby Canyon Creek.

The most ecologically impacted sites of this study were the downstream reaches of Trap and Rucker Creeks. These reaches had the most severe channel incision and erosive banks of the study streams, and are probably contributing excessive sediment to lower reaches and ultimately the South Fork Yuba River. These reaches were also the lowest in diversity, and number of individuals within the reduced habitat. Extreme variations in flow over short time periods has been shown to decrease the ecological health of benthic invertebrate communities. Tailwaters of dams that receive severe daily fluctuations of flow have reduced diversity and density (Gore et al. 1994, Ward 1976) Also, McElravy et al. (1989) found that extreme events such as drought and high rainfall accounted for the variability in benthic fauna distribution. The mechanism for community disturbance from high flows is the physical disturbance of sediment (Powell 1958, Gore et al. 1994). This

phenomenon was seen in Clear Creek, after slightly higher flows were released from the canal for maintenance purposes. Although the release was not great (approximately 6 cfs), the sediment in reach 6 of Clear Creek was small enough (d_{50}=.8 cm) to be easily disturbed by such increases in flow. This distinct disturbance event was followed by a decrease in diversity (total taxa decreased from 17 to 13, Shannon diversity decreased from 2 to 1), a slight increase in evenness (from 7.1 to .95), and a decrease in numbers of individuals per sample (from 91 to 4).

Monitoring and Restoration

There are no flow recorders on the streams intercepted by the Bowman-Spaulding Canal. The long-term amount of flow diverted by the canal, and the seasonal nature of inflow is therefore not known beyond this study. It is difficult to analyze aquatic systems without hydrologic data over significant temporal and spatial scales. Just as important as monitoring flow entering the canal, is monitoring flow leaving the canal. Unpredictable and extreme changes in canal releases appear to have been one of the major causes of physical and ecological impacts to the intercepted streams. Such releases have caused severe channel incision, bank erosion, and depauperate stream communities of questionable persistence. There have also been no previous surveys conducted on the streams. A time series of cross-sectional and longitudinal surveys is invaluable for determining the trends and rates of erosion of channel bottoms and banks. Thus at a minimum, the following monitoring steps should be taken:

1) Continuous flow gauges should be installed on all creeks flowing into the canal. These water resources are valuable economically as well as ecologically. The hydrology of the diverted streams should be thoroughly understood for optimal

operation of the canal, and for the understanding of how the diversions have changed the habitats of downstream reaches.

2) Flow gauges should be installed on all canal release gates. The amount of flow, and rate of increase and decrease of flows released from the canal should be monitored continuously.

3) Periodic longitudinal and cross-sectional surveys of all creeks, above and below the canal should be continued. This information can be used to assess the process of degradation to impacted streams or the benefits of any restoration measures which may be implemented on diverted streams.

4) Periodic monitoring of the aquatic community should be continued through benthic and emergence trap sampling if possible. These methods have been shown to collect different portions of the community, thus a combination will be successful in collecting a majority of the assemblage. This information can be used to track further degradation or improvements to aquatic communities over time in relation to canal operations. Aquatic community health can be gauged by comparing taxa compositions upstream and downstream of the canal and comparing taxa composition among annual collections within each stream.

There are several restoration alternatives that can be outlined as a result of this project. The thorough design and assessment of restoration alternatives is beyond the scope of this report, however, some components of restoration alternatives are provided.

1) Conduct the basic monitoring as described above. Monitoring before and after restorative measures are necessary to determine the success of habitat improvements.

2) A detailed analysis of canal operations should be made, and alternatives to unpredictable, high flow releases from the canal should be sought. Instantaneous releases from the canal due to canal flow management may be

avoided by improving operators' knowledge of stream inflow rates and having more control of canal flow out of Bowman Lake. Thus another use of monitoring flow gauges on inflow streams could be to help calculate the desired canal flow released from Bowman Lake, such that the canal has capacity for stream flow addition.

3) Erosion control devises should be installed in Trap and Rucker Creeks downstream of the canal. Even if canal operations are improved, the over-steepened channel banks will continue to erode until an equilibrium slope is reached. The installation of sediment traps and log weirs in the channel should decrease bank erosion by setting a higher channel elevation and decreasing the difference between channel and bank heights and slopes.

4) Release of excess flow into the hillside between Clear and Fall Creeks should be discontinued. Better management of the canal system should eliminate the need to discharge major water volume in this manner. The artificial channel created by the operations, however, will continue to collect runoff and erode. Thus, erosion control and energy dissipation devices should be installed in the eroded gulley below the canal discharge point between Clear and Fall Creeks. Log weir drop structures and rip rap in the channel and along the eroded sides may help control the further erosion of the hillside and decrease sediment into Clear and Fall Creeks, and ultimately, the South Fork Yuba River.

   If management cannot adequately control excess canal flow, then engineering solutions, such as piping water down to the South Yuba River, or other techniques, should be employed to stop further degradation of the hillslope and stream below the canal.

5) Downstream reaches of diverted streams should be provided with temporally, if not spatially, comparable flows as those in the upstream reach. This report has

shown the direct correlation between stream flow and aquatic community viability. Small pipelines could be constructed that would reconnect the upstream and downstream channels. Though not a true restoration of the physical-biological stream continuum, this connection in flow would insure water, thus habitat, to the downstream channel and would be temporally consistent with the upstream flow regime. In the case of Fall Creek, the upstream and downstream channels are not discontinuous as is the case with the other streams. Flow would not have to be rerouted, but simply increased directly to the downstream reach by lowering the check-dam at the diversion structure.

In conclusion, the Bowman-Spaulding Canal has had severe impacts on associated streams, both physically and ecologically, through drastic water manipulations, increased erosion, and the associated habitat impacts (or complete removal) for aquatic organisms. The stream channels of Trap and Rucker Creeks below the canal, and the eroded hillside between Clear and Fall Creeks cannot feasibly be restored to pre-canal conditions. However there are some operational and physical mechanisms that may be implemented to decrease further degradation of these hillside and stream reaches and the receiving stream, the South Fork Yuba River. Though this study focused on one canal system and its associated streams, the impacts that were revealed should raise concerns that other canal systems on public lands may need investigations as to their long-term ecological impacts.

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APPENDIX A. WATER ANALYSES OF STUDY STREAMS.

Clear Creek field data

	Flow (cfs)		Temperature (C)		Conductivity (uS/cm)		pH	
Date	u/s reach	d/s reach	u/s reach	d/s reach	u/s reach	d/s reach	u/s reach	d/s reach
6/14/95	17.5	0.1	4.2	6.1	16	25.5		
6/27/95	12.7	0.1	11.6	13.2	14.3	15	6.1	6.2
7/9/95	2.4	0.12	10.4	10.4	1.2	13.5	6.5	6.3
7/31/95	0.52	0.1	12	11.3	9.3	21.6	7	6.7
8/12/95		2.5	13.9	11.3	2.6	15.3	6.9	6.9
8/26/95	0.1	0.92	12.5	12.4	20.5	19.3	5.8	5.8
9/9/95	0.1	0.13	10.8	14.1	8.5	15.1	6.2	6.5
10/7/95		0.1		10.4		17.3		
11/19/95		0.1		9.5		17.3		

Fall Creek Field Data

	Flow		Temperature		Conductivity		pH	
Date	u/s reach	d/s reach	u/s reach	d/s reach	u/s reach	d/s reach	u/s reach	d/s reach
6/14/95	89.6	6.5	4.8	4.7	17.9	0.4		
6/27/95	66.5	15.5	7.6	7.7	12.7	15.2	6.3	6.4
7/9/95	16.6	0.1	12.9	13.3	21.3	39	7	6.6
7/31/95	8.2	0.14	15.9	14.8	32.8	32.4	6.6	6.9
8/12/95			15.4	13.5	35.7	16.1	6.9	6.9
8/26/95	2.8	0.045	14.4	13.7	31.8	18.7	6.8	6.8
9/9/95	2.2	0.094	12.4	10.1	49	26.5	6.9	7
10/7/95			6.9	10.4	37.6	38.1		
10/22/95	4.4	0.1	7.9	8	15.6	43.5	5.8	7
11/19/95	4.6	0.1	7.4	7.4	41.8	40.6		

Appendix A. Continued.

Trap Creek Field Data

	Flow		Temperature		Conductivity		pH	
Date	u/s reach	d/s reach	u/s reach	d/s reach	u/s reach	d/s reach	u/s reach	d/s reach
6/14/95	5.1	0.1	5.9	8.1	11.8	39.2		
6/27/95	2.3	0.5	7.8	10.3	12.5	35.6	6.5	6.2
7/9/95	0.6	1.5	10.6	13.1	14.2	40.2	6.4	6.8
7/31/95	0.1	0	12.2	14.3	19.1	19.3	6.9	6.8
8/13/95			10.7	13.4	15.8	44.7	7.2	6.6
8/27/95	0.1	0	11.6	14	17.8	44.3	6.9	7
9/9/95	0.1		13.3	12.8	17	40.6	7	7
10/7/95	0	0	8.2	8.9	20.3	23.5		

Rucker Creek Field Data

	Flow		Temperature		Conductivity		pH	
Date	u/s reach	d/s reach	u/s reach	d/s reach	u/s reach	d/s reach	u/s reach	d/s reach
6/14/95	5.8	0	13.8	7.8	11.7	36.9		
6/27/95	2.1	0	18.4		14.5		6.5	
7/9/95	2.5	0	19	12.7	16.4	54.5	6.6	
7/31/95	0.25	0	18.1	12.8	15.8	48.3	7.1	6.7
8/13/95				12.9		47.4		6.7
8/27/95	0.37		20		14.4		7.1	
9/9/95	0.48	0	17.6		12.4		7	
10/7/95			13.7		11.1			
11/19/95	3.1		10.6		12			

APPENDIX B. BENTHIC SAMPLES COLLECTED BETWEEN 9 JULY AND 19 NOVEMBER 1995.

	Clear, u/s 7/9/95	Clear, u/s 8/1/95	Clear, u/s 8/12/95	Clear, u/s 8/26/95	Clear, u/s 9/9/95	Clear, u/s 10/7/95	Clear, u/s 10/28/95	Clear, u/s 11/19/95	Clear, d/s 7/9/95	Clear, d/s 8/1/95	Clear, d/s 8/12/95	Clear, d/s 8/26/95	Clear, d/s 9/9/95	Clear, d/s 10/7/95	Clear, d/s 10/28/95	Clear, d/s 11/19/95
EPHEMEROPTERA																
Baetidae																
Baetis			1		6				1	1			34	59	20	35
Ephemerellidae																
Caudetella																
Drunella		6	2	1	5				2	43	1			1		
Ephemerella									5					1		
Serratella		1	3							1					33	116
Heptageniidae																
Cinygma			2	4	2				3	5						
Cinygmula	2													4	19	39
Epeorus		1														
Ironodes															2	2
Rhithrogena																
Leptophlebiidae																
Paraleptophlebia	6	2		2	4				9	2			2	8	23	48
Amaletidae																
Ameletus	7	6	2	3	1				6	3					2	9
PLECOPTERA																
Chloroperlidae																
Alloperla																
Kathroperla	2													1		
Plumiperla		1		1	1				2	2					2	
Suwallia									2							
Sweltsa				1										7	3	9
Isoperla																
Kogotus																
Leuctridae																
Despaxia																
Moselia																
Paralectra																
Nemouridae																
Malenka					2				2	2			6	5		
Soyedina															2	1
Visoka																
Zapada			3	1									1	3	10	13

Appendix B. Continued

	Clear, u/s 7/9/95	Clear, u/s 8/1/95	Clear, u/s 8/12/95	Clear, u/s 8/26/95	Clear, u/s 9/9/95	Clear, u/s 10/7/95	Clear, u/s 10/28/95	Clear, u/s 11/19/95	Clear, d/s 7/9/95	Clear, d/s 8/1/95	Clear, d/s 8/12/95	Clear, d/s 8/26/95	Clear, d/s 9/9/95	Clear, d/s 10/7/95	Clear, d/s 10/28/95	Clear, d/s 11/19/95
Perlidae																
Calineuria		1	1	3	2				5	3			3	2	3	5
Doroneuria																
Hesperoperla														2		1
Perlodidae																
Isoperla																
Oroperla																
Osobenus														36	20	10
Perlinodes														17	25	4
Rickera																
Skwala					4											
TRICHOPTERA																
Brachycentridae																
Micrasema																
Calamoceratidae																
Heteroplectron																
Glossosomatidae																
Agapetus														1	3	1
Glossosoma																
Helicopsychidae																
Helicopsyche																
Hydropsychidae									1							
Arctpsyche														1		
Ceratopsyche														1	4	5
Parapsyche				1												
Hydroptilidae																
Ochrotrichia														2	5	1
Lepidostomatidae																
Lepidostoma		1							1	2					17	12
Limnephilidae				1												
Apatania					1											
Chyranda																
Clostoeca																1
Ecclisomyia																
Homophlax																
Lenarchus															1	
Psychoglypha				1												

Appendix B. Continued

	Clear, u/s 7/9/95	Clear, u/s 8/1/95	Clear, u/s 8/12/95	Clear, u/s 8/26/95	Clear, u/s 9/9/95	Clear, u/s 10/7/95	Clear, u/s 10/28/95	Clear, u/s 11/19/95	Clear, d/s 7/9/95	Clear, d/s 8/1/95	Clear, d/s 8/12/95	Clear, d/s 8/26/95	Clear, d/s 9/9/95	Clear, d/s 10/7/95	Clear, d/s 10/28/95	Clear, d/s 11/19/95
Philopotamidae																
Dolophilodes																
Wormaldia														1		
Phryganaeidae									1							
Polycentropodidae																
Polycentropus				1					6	3						
Rhyacophilidae																
Rhyacophila				1	1				4	12			3	4	5	3
Sericostomatidae																
Gumaga										1		1			1	
Uenoidae																
Neophylax	1															
Oligophlebodes																
DIPTERA																
Ceratopogonidae			1											2		
Chironomidae	3		2	5	2				1	5	1	1	8	30	2	2
Dixidae													1			
Nymphomyiidae																
Simuliidae			1										1	22	15	3
Stratiomyidae		2		1	1											
Tabanidae																
Tipulidae	2	3	2	4	9						2	3	12	4	1	8
MEGALOPTERA																
Corydalidae																
Orohermes	1			1	1				2	3					1	3
Sialidae																
Sialis									1	1						

Appendix B. Continued.

	Clear, u/s 7/9/95	Clear, u/s 8/1/95	Clear, u/s 8/12/95	Clear, u/s 8/26/95	Clear, u/s 9/9/95	Clear, u/s 10/7/95	Clear, u/s 10/28/95	Clear, u/s 11/19/95	Clear, d/s 7/9/95	Clear, d/s 8/1/95	Clear, d/s 8/12/95	Clear, d/s 8/26/95	Clear, d/s 9/9/95	Clear, d/s 10/7/95	Clear, d/s 10/28/95	Clear, d/s 11/19/95
COLEOPTERA																
Dytiscidae *Heteroplactron*					1										1	
Elmidae			1	1	2											1
Psephenidae *Eubrianax*																
Staphylinidae																
Tenebrionidae									1	2						
ODONATA																
Coenagrionidae *Argia*																
Gomphidae *Octogomphus*														1		1

Appendix B. Continued.

	Fall, u/s 7/9/95	Fall, u/s 8/1/95	Fall, u/s 8/12/95	Fall, u/s 8/26/95	Fall, u/s 9/9/95	Fall, u/s 10/7/95	Fall, u/s 10/28/95	Fall, u/s 11/19/95	Fall, d/s 7/9/95	Fall, d/s 8/1/95	Fall, d/s 8/12/95	Fall, d/s 8/26/95	Fall, d/s 9/9/95	Fall, d/s 10/7/95	Fall, d/s 10/28/95	Fall, d/s 11/19/95
EPHEMEROPTERA																
Baetidae																
Baetis	1	2	6	5	1	5	2	5		1	10	21	22	6	11	11
Ephemerellidae																
Caudetella						2		2								
Drunella		8	5	1	11	23	16	18	1	2					4	6
Ephemerella	2								1							
Serratella		3	8	4	4					1		4			6	3
Heptageniidae																
Cinygma				1								1		2		
Cinygmula	10	2			10	2		4	4	1	4	5	17	17	84	131
Epeorus	3	2	2	2		1		1	1							
Ironodes	1	2	2			5	1	6			1				4	4
Rhithrogena	1			1	6	12	17	17							2	4
Leptophlebiidae																
Paraleptophlebia					1	1	3	8	10		1	1	3	18	12	8
Amaletidae																
Ameletus		2	2	4	1			1	2	5	5	1	6	13	5	4
PLECOPTERA																
Chloroperlidae																
Alloperla									1							
Kathroperla							1	1								1
Plumiperla	1								9		1	1				
Suwallia		3							6	2						
Sweltsa				1		2	1	7					4	8	13	11
Isoperla																
Kogotus																
Leuctridae																
Despaxia													3			
Moselia				1												
Paralectra													1			3
Nemouridae																
Malenka				2	3					2	3	2	1			
Soyedina																
Visoka					4		2				5	1	8	13	4	6
Zapada			1		1	2	4	41					2	17	52	33

Appendix B. Continued.

	Fall, u/s 7/9/95	Fall, u/s 8/1/95	Fall, u/s 8/12/95	Fall, u/s 8/26/95	Fall, u/s 9/9/95	Fall, u/s 10/7/95	Fall, u/s 10/28/95	Fall, u/s 11/19/95	Fall, d/s 7/9/95	Fall, d/s 8/1/95	Fall, d/s 8/12/95	Fall, d/s 8/26/95	Fall, d/s 9/9/95	Fall, d/s 10/7/95	Fall, d/s 10/28/95	Fall, d/s 11/19/95
Perlidae																
Calineuria	3	4	1	5	9	9	6	11	14	8	4	7	16	5	15	17
Doroneuria						2	2	3							2	1
Hesperoperla																
Perlodidae																
Isoperla					1											
Oroperla			1					1							1	
Osobenus													1	1	5	5
Perlinodes													1		1	1
Rickera														1		
Skwala														1		
TRICHOPTERA																
Brachycentridae																
Micrasema		1								4						
Calamoceratidae																
Heteroplectron																
Glossosomatidae			1													
Agapetus		1		6	10	2						4	10			1
Glossosoma									1							
Helicopsychidae																
Helicopsyche																
Hydropsychidae						1			1							
Arctpsyche																
Ceratopsyche	1	4	4	6	6	13	3	9		1	1			1	4	10
Parapsyche			1	1	1											
Hydroptilidae																
Ochrotrichia						1									2	1
Lepidostomatidae																
Lepidostoma		2		1			3		1	2				1	1	2
Limnephilidae																
Apatania												1		1	1	
Chyranda																
Clostoeca																
Ecclisomyia																
Homophlax															1	
Lenarchus																
Psychoglypha									1							

Appendix B. Continued.

	Fall, u/s 7/9/95	Fall, u/s 8/1/95	Fall, u/s 8/12/95	Fall, u/s 8/26/95	Fall, u/s 9/9/95	Fall, u/s 10/7/95	Fall, u/s 10/28/95	Fall, u/s 11/19/95	Fall, d/s 7/9/95	Fall, d/s 8/1/95	Fall, d/s 8/12/95	Fall, d/s 8/26/95	Fall, d/s 9/9/95	Fall, d/s 10/7/95	Fall, d/s 10/28/95	Fall, d/s 11/19/95
Philopotamidae											1					
Dolophilodes															1	
Wormaldia					2											
Phryganaeidae																
Polycentropodidae																
Polycentropus									2	1						1
Rhyacophilidae																
Rhyacophila		1	2	3	12	8	2	10			1		1	6	6	7
Sericostomatidae																
Gumaga		1		2			3	5	1		1		2	2		
Uenoidae																
Neophylax																
Oligophlebodes							1									
DIPTERA																
Ceratopogonidae														1		
Chironomidae	1	4	2	3	3	3		2	1	9		2	14	12	21	25
Dixidae																
Nymphomyiidae										1						
Simuliidae					1	3		2								
Stratiomyidae					1		1	1			2	1				1
Tabanidae																
Tipulidae		8	2	5	2	3	2	3	2	2		4	6	4	5	6
MEGALOPTERA																
Corydalidae																
Orohermes				1		1			1		1			1		1
Sialidae																
Sialis																

Appendix B. Continued.

	Fall, u/s 7/9/95	Fall, u/s 8/1/95	Fall, u/s 8/12/95	Fall, u/s 8/26/95	Fall, u/s 9/9/95	Fall, u/s 10/7/95	Fall, u/s 10/28/95	Fall, u/s 11/19/95	Fall, d/s 7/9/95	Fall, d/s 8/1/95	Fall, d/s 8/12/95	Fall, d/s 8/26/95	Fall, d/s 9/9/95	Fall, d/s 10/7/95	Fall, d/s 10/28/95	Fall, d/s 11/19/95
COLEOPTERA																
Dytiscidae *Heteroplactron*										1		1				
Elmidae		1	1				1	1						1		
Psephenidae *Eubrianax*																1
Staphylinidae										1						
Tenebrionidae																
ODONATA																
Coenagrionidae *Argia*																
Gomphidae *Octogomphus*																

Appendix B. Continued.

	Trap, u/s 7/9/95	Trap, u/s 8/1/95	Trap, u/s 8/12/95	Trap, u/s 8/26/95	Trap, u/s 9/9/95	Trap, u/s 10/7/95	Trap, u/s 10/28/95	Trap, u/s 11/19/95	Trap, d/s 7/9/95	Trap, d/s 8/1/95	Trap, d/s 8/12/95	Trap, d/s 8/26/95	Trap, d/s 9/9/95	Trap, d/s 10/7/95	Trap, d/s 10/28/95	Trap, d/s 11/19/95
EPHEMEROPTERA																
Baetidae																
Baetis	3	3	9	12	11					2	12	4				
Ephemerellidae																
Caudetella																
Drunella	5															
Ephemerella									1							
Serratella					1											
Heptageniidae																
Cinygma		3	6	2	5				14	6	8	9				
Cinygmula	16	3	2	1	1					1						
Epeorus	2															
Ironodes		2	2	8	1					2						
Rhithrogena																
Leptophlebiidae																
Paraleptophlebia	10	1	2		4							1				
Amaletidae																
Ameletus	17	16			5				9	6	9	4				
PLECOPTERA																
Chloroperlidae																
Alloperla																
Kathroperla																
Plumiperla	2	2							2							
Suwallia																
Sweltsa		2		1	8						2					
Isoperla																
Kogotus	1															
Leuctridae																
Despaxia																
Moselia																
Paralectra																
Nemouridae																
Malenka	2	4	2	5	1					2						
Soyedina										1						
Visoka		6	1	2	3											
Zapada				2					1	1		2				

Appendix B. Continued.

	Trap, u/s 7/9/95	Trap, u/s 8/1/95	Trap, u/s 8/12/95	Trap, u/s 8/26/95	Trap, u/s 9/9/95	Trap, u/s 10/7/95	Trap, u/s 10/28/95	Trap, u/s 11/19/95	Trap, d/s 7/9/95	Trap, d/s 8/1/95	Trap, d/s 8/12/95	Trap, d/s 8/26/95	Trap, d/s 9/9/95	Trap, d/s 10/7/95	Trap, d/s 10/28/95	Trap, d/s 11/19/95
Perlidae																
Calineuria																
Doroneuria					1											
Hesperoperla																
Perlodidae																
Isoperla		3	3	14	25				1							
Oroperla																
Osobenus																
Perlinodes																
Rickera																
Skwala																
TRICHOPTERA																
Brachycentridae																
Micrasema																
Calamoceratidae																
Heteroplectron											1					
Glossosomatidae																
Agapetus					1											
Glossosoma																
Helicopsychidae																
Helicopsyche																
Hydropsychidae																
Arctpsyche																
Ceratopsyche									4							
Parapsyche			1	2						1		1				
Hydroptilidae																
Ochrotrichia																
Lepidostomatidae																
Lepidostoma		1		1	1				2	2	3					
Limnephilidae									1							
Apatania																
Chyranda																
Clostoeca																
Ecclisomyia																
Homophlax																
Lenarchus																
Psychoglypha																

Appendix B. Continued.

	Trap, u/s 7/9/95	Trap, u/s 8/1/95	Trap, u/s 8/12/95	Trap, u/s 8/26/95	Trap, u/s 9/9/95	Trap, u/s 10/7/95	Trap, u/s 10/28/95	Trap, u/s 11/19/95	Trap, d/s 7/9/95	Trap, d/s 8/1/95	Trap, d/s 8/12/95	Trap, d/s 8/26/95	Trap, d/s 9/9/95	Trap, d/s 10/7/95	Trap, d/s 10/28/95	Trap, d/s 11/19/95
Philopotamidae																
Dolophilodes	1		1						3							
Wormaldia		2														
Phryganaeidae																
Polycentropodidae																
Polycentropus									2		1					
Rhyacophilidae																
Rhyacophila	2	1			1											
Sericostomatidae																
Gumaga											1					
Uenoidae									1							
Neophylax	1								3							
Oligophlebodes																
DIPTERA																
Ceratopogonidae																
Chironomidae		4	2	2												
Dixidae				1	1											
Nymphomyiidae																
Simuliidae																
Stratiomyidae	1	1		1	2											
Tabanidae																
Tipulidae		2	2	6	8							1				
MEGALOPTERA																
Corydalidae																
Orohermes																
Sialidae																
Sialis			1													

Appendix B. Continued.

	Trap, u/s 7/9/95	Trap, u/s 8/1/95	Trap, u/s 8/12/95	Trap, u/s 8/26/95	Trap, u/s 9/9/95	Trap, u/s 10/7/95	Trap, u/s 10/28/95	Trap, u/s 11/19/95	Trap, d/s 7/9/95	Trap, d/s 8/1/95	Trap, d/s 8/12/95	Trap, d/s 8/26/95	Trap, d/s 9/9/95	Trap, d/s 10/7/95	Trap, d/s 10/28/95	Trap, d/s 11/19/95
COLEOPTERA																
Dytiscidae																
Heteroplactron			1						1		1					
Elmidae																
Psephenidae																
Eubrianax																
Staphylinidae																
Tenebrionidae																
ODONATA																
Coenagrionidae																
Argia																
Gomphidae																
Octogomphus																

Appendix B. Continued.

	Rucker,u/s 7/9/95	Rucker,u/s 8/1/95	Rucker,u/s 8/26/95	Rucker,u/s 9/9/95	Rucker,u/s 10/7/95	Rucker,u/s 11/19/95	Rucker,d/s 7/9/95	Rucker,d/s 8/1/95	Rucker,d/s 8/26/95	Rucker,d/s 9/9/95	Rucker,d/s 10/7/95	Rucker,d/s 11/19/95
EPHEMEROPTERA												
Baetidae												
Baetis	2	4	3	1	2	6						
Ephemerellidae												
Caudetella												
Drunella												
Ephemerella												
Serratella					1	11						
Heptageniidae												
Cinygma				1			1	3				
Cinygmula				1		2						
Epeorus		8	1					1				
Ironodes					4	20						
Rhithrogena												
Leptophlebiidae												
Paraleptophlebia	1			10	3	18	2					
Amaletidae												
Ameletus							3					
PLECOPTERA												
Chloroperlidae												
Alloperla												
Kathroperla												
Plumiperla							1					
Suwallia												
Sweltsa					4	1	1	1				
Isoperla												
Kogotus												
Leuctridae												
Despaxia												
Moselia												
Paralectra												
Nemouridae												
Malenka			1	3	1							
Soyedina												
Visoka												
Zapada						9		1				

Appendix B. Continued.

	Rucker,u/s 7/9/95	Rucker,u/s 8/1/95	Rucker,u/s 8/26/95	Rucker,u/s 9/9/95	Rucker,u/s 10/7/95	Rucker,u/s 11/19/95	Rucker,d/s 7/9/95	Rucker,d/s 8/1/95	Rucker,d/s 8/26/95	Rucker,d/s 9/9/95	Rucker,d/s 10/7/95	Rucker,d/s 11/19/95
Perlidae												
Calineuria	15	11	13	19	11	10						
Doroneuria				3								
Hesperoperla	1	6	2	2	1			1				
Perlodidae												
Isoperla												
Oroperla												
Osobenus						1						
Perlinodes												
Rickera												
Skwala												
TRICHOPTERA												
Brachycentridae												
Micrasema												
Calamoceratidae												
Heteroplectron	1		1									
Glossosomatidae												
Agapetus												
Glossosoma												
Helicopsychidae												
Helicopsyche		3	3									
Hydropsychidae												
Arctpsyche												
Ceratopsyche		5	4		1	33						
Parapsyche				1								
Hydroptilidae												
Ochrotrichia		1										
Lepidostomatidae												
Lepidostoma		1		1	1							
Limnephilidae				1								
Apatania			1									
Chyranda												
Clostoeca												
Ecclisomyia												
Homophlax												
Lenarchus												
Psychoglypha							2					

Appendix B. Continued.

	Rucker,u/s 7/9/95	Rucker,u/s 8/1/95	Rucker,u/s 8/26/95	Rucker,u/s 9/9/95	Rucker,u/s 10/7/95	Rucker,u/s 11/19/95	Rucker,d/s 7/9/95	Rucker,d/s 8/1/95	Rucker,d/s 8/26/95	Rucker,d/s 9/9/95	Rucker,d/s 10/7/95	Rucker,d/s 11/19/95
Philopotamidae			1									
Dolophilodes												
Wormaldia		3										
			1									
Phryganaeidae												
Polycentropodidae	1											
Polycentropus	1											
Rhyacophilidae												
Rhyacophila	3	14	3	3	2	2						
Sericostomatidae												
Gumaga	1			1		1						
Uenoidae												
Neophylax												
Oligophlebodes												
DIPTERA												
Ceratopogonidae				1		1						
Chironomidae	1	1	4	7		2						
Dixidae												
Nymphomyiidae												
Simuliidae					1							
Stratiomyidae												
Tabanidae					1							
Tipulidae				3	3	8		1				
MEGALOPTERA												
Corydalidae												
Orohermes	1	3	4	5								
Sialidae												
Sialis												

Appendix B. Continued.

	Rucker,u/s 7/9/95	Rucker,u/s 8/1/95	Rucker,u/s 8/26/95	Rucker,u/s 9/9/95	Rucker,u/s 10/7/95	Rucker,u/s 11/19/95	Rucker,d/s 7/9/95	Rucker,d/s 8/1/95	Rucker,d/s 8/26/95	Rucker,d/s 9/9/95	Rucker,d/s 10/7/95	Rucker,d/s 11/19/95
COLEOPTERA												
Dytiscidae												
Heteroplactron			1									
Elmidae		1	2		1			1				
Psephenidae												
Eubrianax			2	2								
Staphylinidae												
Tenebrionidae												
ODONATA												
Coenagrionidae												
Argia			1			1						
Gomphidae												
Octogomphus		1	2	5	1	4		1				

APPENDIX C. ARTIFICIAL SUBSTRATE SAMPLES COLLECTED BETWEEN 1 AUGUST AND 19 NOVEMBER 1995.

	Clear, u/s VIII/1/95			Clear, u/s VIII/12/95			Clear, u/s VIII/26/95			Clear, u/s IX/9/95			Clear,d/s VIII/1/95			Clear,d/s VIII/12/95			Clear,d/s VIII/26/95		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
EPHEMEROPTERA																					
Baetidae																					
Baetis						2				1											
Ephemerellidae																					
Drunella					1					1			3								
Serratella													1								
Heptageniidae																					
Cinygma							1				1										
Cinygmula																					
Leptophlebiidae																					
Paraleptophlebia																					
Siphlonuridae																					
Ameletus														1							
PLECOPTERA																					
Chloroperlidae																					
Sweltsa															1						
Nemouridae																					
Malenka								1													
Zapada				1						2	1										
Perlidae																					
Calineuria																					
Perlodidae																					
Isoperla																					
Osobenus																					
TRICHOPTERA																					
Glossosomatidae																					
Agapetus																					
Helicopsychidae																					
Helicopsyche																					
Hydropsychidae																					
Arctpsyche																					
Ceratopsyche										1				1							
Parapsyche				2																	

Appendix C. Continued.

	Clear, u/s VIII/1/95	Clear, u/s VIII/12/95	Clear, u/s VIII/26/95	Clear, u/s IX/9/95	Clear,d/s VIII/1/95	Clear,d/s VIII/12/95	Clear,d/s VIII/26/95
Hydroptilidae							
Ochrotrichia							
Lepidostomatidae							
Lepidostoma							
Limnephilidae							
Apatania							
Neophylax							1
Philopotamidae							
Wormaldia							
Polycentropodidae							
Polycentropus				1		3	
Rhyacophilidae							
Rhyacophila					1		
DIPTERA							
Chironomidae		1 2		1	2		
Dixidae				4			
Simuliidae	1	1 16		3 2			
Tipulidae					1		
ODONATA							
Gomphidae							
Octogomphus							

Appendix C. Continued.

	Clear,d/s IX/9/95			Clear,d/s X/7/95			Clear,d/s X/28/95			Fall,u/s VIII/1/95			Fall,u/s VIII/12/95			Fall,u/s VIII/26/95			Fall,u/s IX/9/95		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
EPHEMEROPTERA																					
Baetidae																					
Baetis	1	1	2													3			1	1	
Ephemerellidae																					
Drunella																1					2
Serratella									2												
Heptageniidae																					
Cinygma																					
Cinygmula									1												
Leptophlebiidae																					
Paraleptophlebia		1																			
Siphlonuridae																					
Ameletus																					
PLECOPTERA																					
Chloroperlidae																					
Sweltsa		1																			
Nemouridae																					
Malenka	1	1																			
Zapada	1		1		1																
Perlidae																					
Calineuria						1															
Perlodidae																					
Isoperla																					
Osobenus					1																
TRICHOPTERA																					
Glossosomatidae																					
Agapetus				7	2	5		1	24							1	3		3		3
Helicopsychidae																					
Helicopsyche																					
Hydropsychidae																					
Arctpsyche					1																
Ceratopsyche																1	1				
Parapsyche																					

Appendix C. Continued.

	Clear,d/s IX/9/95		Clear,d/s X/7/95	Clear,d/s X/28/95		Fall,u/s VIII/1/95	Fall,u/s VIII/12/95	Fall,u/s VIII/26/95	Fall,u/s IX/9/95
Hydroptilidae									
Ochrotrichia			2	1					2
Lepidostomatidae									
Lepidostoma							1		
Limnephilidae									
Apatania									
Neophylax									
Philopotamidae									
Wormaldia					1				
Polycentropodidae									
Polycentropus									
Rhyacophilidae									
Rhyacophila	1								
DIPTERA									
Chironomidae				10	1	1	1		1
Dixidae									1
Simuliidae	1	4							
Tipulidae									
ODONATA									
Gomphidae									
Octogomphus									

Appendix C. Continued.

	Fall,u/s X/7/95			Fall,u/s X/28/95			Fall,d/s VIII/1/95			Fall,d/s VIII/12/95			Fall,d/s VIII/26/95			Fall,d/s IX/9/95			Fall,d/s X/7/95		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
EPHEMEROPTERA																					
Baetidae																					
Baetis																	2		1		
Ephemerellidae																					
Drunella				2																	
Serratella																					
Heptageniidae																					
Cinygma																					
Cinygmula																					
Leptophlebiidae																					
Paraleptophlebia								1													
Siphlonuridae																					
Ameletus																					
PLECOPTERA																					
Chloroperlidae																					
Sweltsa																					
Nemouridae																					
Malenka																					
Zapada	1																				
Perlidae																					
Calineuria										1							1				
Perlodidae																					
Isoperla																					
Osobenus																					
TRICHOPTERA																					
Glossosomatidae																					
Agapetus	1									1		1									
Helicopsychidae																					
Helicopsyche																					
Hydropsychidae																					
Arctpsyche																					
Ceratopsyche																					
Parapsyche																					

Appendix C. Continued.

	Fall,u/s X/7/95	Fall,u/s X/28/95	Fall,d/s VIII/1/95	Fall,d/s VIII/12/95	Fall,d/s VIII/26/95	Fall,d/s IX/9/95	Fall,d/s X/7/95
Hydroptilidae							
Ochrotrichia				1		3 3	10 3
Lepidostomatidae							
Lepidostoma							
Limnephilidae							
Apatania							
Neophylax							
Philopotamidae							
Wormaldia							
Polycentropodidae							
Polycentropus				1	1 1		1
Rhyacophilidae							
Rhyacophila							
DIPTERA							
Chironomidae				8 1	2	1 5	8 6 7
Dixidae							
Simuliidae							
Tipulidae							
ODONATA							
Gomphidae							
Octogomphus							

Appendix C. Continued.

	Fall,d/s X/28/95			Trap,u/s VIII/1/95			Trap,u/s VIII/12/95			Trap,u/s VIII/26/95			Trap,u/s IX/9/95			Trap,d/s VIII/1/95			Trap,d/s VIII/12/95		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
EPHEMEROPTERA																					
Baetidae																					
Baetis							1				2										
Ephemerellidae																					
Drunella				1																	
Serratella																					
Heptageniidae																					
Cinygma																			1		
Cinygmula																					
Leptophlebiidae																					
Paraleptophlebia																					
Siphlonuridae																					
Ameletus						1															
PLECOPTERA																					
Chloroperlidae																					
Sweltsa																					
Nemouridae																					
Malenka																					
Zapada																					
Perlidae																					
Calineuria			1																		
Perlodidae																					
Isoperla							1														
Osobenus																					
TRICHOPTERA																					
Glossosomatidae																					
Agapetus																					
Helicopsychidae																					
Helicopsyche																					
Hydropsychidae																					
Arctpsyche																					
Ceratopsyche																					
Parapsyche																					

Appendix C. Continued.

	Fall,d/s X/28/95			Trap,u/s VIII/1/95	Trap,u/s VIII/12/95	Trap,u/s VIII/26/95	Trap,u/s IX/9/95	Trap,d/s VIII/1/95	Trap,d/s VIII/12/95
Hydroptilidae									
Ochrotrichia	1		4						
Lepidostomatidae									
Lepidostoma									
Limnephilidae							1		
Apatania									
Neophylax									
Philopotamidae									
Wormaldia									
Polycentropodidae									
Polycentropus			1		1				
Rhyacophilidae									
Rhyacophila									
DIPTERA									
Chironomidae	11	7	6			2			
Dixidae									
Simuliidae									
Tipulidae									
ODONATA									
Gomphidae									
Octogomphus									

Appendix C. Continued.

	Trap,d/s VIII/26/95			Trap,d/s IX/9/95			Rucker,u/s VIII/1/95			Rucker,u/s VIII/26/95			Rucker,u/s IX/9/95			Rucker,d/s VIII/1/95			Rucker,d/s X/7/95		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
EPHEMEROPTERA																					
Baetidae																					
Baetis										1	1		1	2					2		
Ephemerellidae																					
Drunella																					
Serratella																					
Heptageniidae																					
Cinygma		1																1			
Cinygmula																					
Leptophlebiidae																					
Paraleptophlebia																					
Siphlonuridae																					
Ameletus																					
PLECOPTERA																					
Chloroperlidae																					
Sweltsa																1		3			
Nemouridae																					
Malenka																					
Zapada																					
Perlidae																					
Calineuria																					
Perlodidae																					
Isoperla																					
Osobenus																					
TRICHOPTERA																					
Glossosomatidae																					
Agapetus																					
Helicopsychidae																					
Helicopsyche															1						
Hydropsychidae																					
Arctpsyche																					
Ceratopsyche																					
Parapsyche																					

Appendix C. Continued.

	Trap,d/s VIII/26/95	Trap,d/s IX/9/95	Rucker,u/s VIII/1/95	Rucker,u/s VIII/26/95	Rucker,u/s IX/9/95		Rucker,d/s VIII/1/95	Rucker,d/s X/7/95
Hydroptilidae								
Ochrotrichia	2			1	5	3		
Lepidostomatidae								
Lepidostoma							1	
Limnephilidae								
Apatania								1
Neophylax								
Philopotamidae								
Wormaldia								
Polycentropodidae								
Polycentropus								
Rhyacophilidae								
Rhyacophila								
DIPTERA								
Chironomidae	2	2		1	2	5		
Dixidae								
Simuliidae								
Tipulidae								
ODONATA								
Gomphidae								
Octogomphus							1	

Appendix D. Emergence trap samples collected between 12 August and 19 November 1995.

	Fall Creek,u/s VIII-12-95			Fall Creek,u/s VIII-26-95			Fall Creek,u/s IX-6-95			Fall Creek,u/s IX-12-95		
	1	2	3	1	2	3	1	2	3	1	2	3
EPHEMEROPTERA	1	0	4	2	1	1	0	4	0	0	0	0
PLECOPTERA	6	4	5	8	1	5	0	0	0	0	0	0
TRICHOPTERA	5	2	5	9	5	10	4	2	0	0	1	0
DIPTERA	16	55	14	38	149	47	79	151	37	3	35	24
COLEOPTERA	0	0	0	1	0	0	0	0	0	0	0	0
HYMENOPTERA	2	3	1	3	2	1	1	4	5	0	2	1
HOMOPTERA	1	2	1	1	2	1	4	2	0	0	0	0
LEPIDOPTERA	1	2	4	3	0	1	0	0	1	0	0	0
HEMIPTERA	0	0	1	0	0	0	0	0	0	0	0	1
THYSANOPTERA	0	0	0	0	1	0	0	0	4	0	0	0

	Fall Creek,u/s IX-21-95			Fall Creek,u/s X-7-95			Fall Creek,u/s X-12-95			Fall Creek,u/s X-22-95	
	1	2	3	1	2	3	1	2	3	1	2
EPHEMEROPTERA	0	0	0	0	2	10	1	0	0	1	0
PLECOPTERA	4	0	8	2	13	10	3	0	0	2	1
TRICHOPTERA	0	0	0	0	11	14	1	0	0	10	4
DIPTERA	15	5	42	2	18	29	5	0	20	18	4
COLEOPTERA	0	0	0	0	1	1	0	0	0	0	1
HYMENOPTERA	1	1	3	0	0	0	0	0	4	0	1
HOMOPTERA	1	0	6	1	7	9	3	0	0	1	5
LEPIDOPTERA	0	0	0	0	1	0	0	0	0	0	0
HEMIPTERA	0	0	0	0	1	0	0	0	0	0	0
THYSANOPTERA	0	0	0	0	2	1	0	0	0	1	2

	Fall Creek,u/s X-27-95			Fall Creek,u/s XI-7-95			Fall Creek,u/s XI-19-95		
	1	2	3	1	2	3	1	2	3
EPHEMEROPTERA	2	2	1	1	0	0	0	0	0
PLECOPTERA	0	4	0	0	0	0	0	1	1
TRICHOPTERA	0	6	2	0	1	0	0	0	1
DIPTERA	3	3	15	14	7	2	5	0	15
COLEOPTERA	0	0	0	0	0	0	0	0	0
HYMENOPTERA	1	0	2	1	1	0	0	0	0
HOMOPTERA	0	0	0	0	0	0	0	0	0
LEPIDOPTERA	0	0	0	0	0	0	0	0	0
HEMIPTERA	0	1	0	0	0	0	0	1	0
THYSANOPTERA	3	1	1	0	0	1	1	0	0

Appendix D. Continued.

	Fall Creek,d/s VIII-12-95			Fall Creek,d/s VIII-26-95			Fall Creek,d/s IX-6-95			Fall Creek,d/s IX-12-95		
	1	2	3	1	2	3	1	2	3	1	2	3
EPHEMEROPTERA	1	0	0	0	0	1	0	0	0	0	0	0
PLECOPTERA	6	2	2	0	1	2	0	0	0	0	0	0
TRICHOPTERA	0	0	0	0	0	0	0	0	0	0	0	1
DIPTERA	12	34	13	42	48	35	36	85	17	11	8	47
COLEOPTERA	0	0	0	0	0	0	0	0	0	1	0	0
HYMENOPTERA	0	4	2	3	0	1	1	4	1	0	0	1
HOMOPTERA	5	8	3	1	3	10	1	9	2	2	1	1
LEPIDOPTERA	0	0	0	0	1	1	1	0	0	0	0	0
HEMIPTERA	0	0	0	0	0	0	0	0	0	0	0	0
THYSANOPTERA	0	0	0	0	0	0	0	0	0	0	0	0

	Fall Creek,d/s IX-21-95			Fall Creek,d/s X-7-95			Fall Creek,d/s X-12-95			Fall Creek,d/s X-22-95		
	1	2	3	1	2	3	1	2	3	1	2	3
EPHEMEROPTERA	0	0	0	1	1	0	4	2	0	2	0	8
PLECOPTERA	0	3	4	6	9	2	3	7	6	13	12	4
TRICHOPTERA	0	0	2	7	2	0	1	4	0	2	2	4
DIPTERA	18	31	92	64	56	10	13	19	8	36	16	33
COLEOPTERA	0	0	0	1	0	0	0	0	0	0	0	0
HYMENOPTERA	2	0	0	1	4	0	2	1	0	2	0	2
HOMOPTERA	2	4	22	7	8	6	2	1	1	5	2	1
LEPIDOPTERA	0	1	0	1	1	0	0	0	0	0	0	0
HEMIPTERA	0	0	0	1	0	0	0	0	0	0	0	0
THYSANOPTERA	0	0	0	1	0	0	0	0	0	0	0	0

	Fall Creek,d/s X-27-95			Fall Creek,d/s XI-7-95			Fall Creek,d/s XI-19-95		
	1	2	3	1	2	3	1	2	3
EPHEMEROPTERA	2	1	0	0	0	0	0	0	0
PLECOPTERA	1	0	3	2	3	0	2	3	1
TRICHOPTERA	1	3	0	0	0	1	0	0	0
DIPTERA	17	13	29	11	14	16	8	10	14
COLEOPTERA	0	0	0	0	1	0	0	0	0
HYMENOPTERA	1	0	1	0	0	0	1	0	2
HOMOPTERA	1	0	0	0	1	1	0	0	2
LEPIDOPTERA	0	0	0	0	0	0	0	0	0
HEMIPTERA	0	0	0	0	0	0	0	0	0
THYSANOPTERA	0	1	1	0	0	0	1	0	0

Appendix D. Continued.

	Trap Creek,u/s IX-6-95			Trap Creek,u/s IX-12-95			Trap Creek,u/s IX-21-95		
	1	2	3	1	2	3	1	2	3
EPHEMEROPTERA	0	0	0	0	0	1	0	0	0
PLECOPTERA	2	1	1	0	0	0	2	2	1
TRICHOPTERA	0	0	0	1	1	0	1	1	0
DIPTERA	32	47	13	6	14	14	29	54	27
COLEOPTERA	0	0	0	0	0	0	0	0	0
HYMENOPTERA	0	0	5	0	1	2	0	5	0
HOMOPTERA	0	1	1	0	1	0	0	0	0
LEPIDOPTERA	0	0	0	0	0	0	0	0	0
HEMIPTERA	0	0	0	0	0	0	0	0	1
THYSANOPTERA	1	2	1	0	0	0	0	0	0

	TrapCreek,u/s X-7-95			Trap Creek,u/s X-12-95			Trap Creek,u/s X-22-95		
	1	2	3	1	2	3	1	2	3
EPHEMEROPTERA	1	0	0	0	0	0	0	0	0
PLECOPTERA	3	2	5	0	2	0	0	1	1
TRICHOPTERA	1	1	1	0	0	0	0	0	2
DIPTERA	50	34	108	7	113	9	8	34	49
COLEOPTERA	0	0	0	0	1	0	0	0	0
HYMENOPTERA	1	0	5	0	0	1	0	0	2
HOMOPTERA	0	0	4	0	0	0	1	0	0
LEPIDOPTERA	1	0	1	0	0	0	1	0	1
HEMIPTERA	0	0	0	0	0	0	0	0	0
THYSANOPTERA	0	0	0	0	0	0	0	0	0

	Trap Creek,u/s X-29-95			Trap Creek,u/s XI-7-95			Trap Creek,u/s XI-19-95		
	1	2	3	1	2	3	1	2	3
EPHEMEROPTERA	0	0	0	0	0	0	0	0	0
PLECOPTERA	3	0	0	1	2	0	4	0	7
TRICHOPTERA	1	0	0	0	1	0	0	0	0
DIPTERA	35	11	22	7	26	27	14	49	29
COLEOPTERA	0	0	0	0	0	0	0	0	0
HYMENOPTERA	0	0	0	0	0	0	2	0	0
HOMOPTERA	2	0	0	0	0	0	0	0	0
LEPIDOPTERA	0	0	0	0	0	0	0	0	0
HEMIPTERA	0	0	0	0	0	0	0	1	0
THYSANOPTERA	0	0	1	0	0	1	0	0	0

Appendix D. Continued.

	Trap Creek,d/s IX-6-95			Trap Creek,d/s IX-12-95		Trap Creek,d/s IX-21-95		
	1	2	3	1	2	1	2	3
EPHEMEROPTERA	1	0	0	0	0	2	0	0
PLECOPTERA	0	0	0	0	0	3	4	1
TRICHOPTERA	2	1	0	2	1	1	1	1
DIPTERA	55	26	75	10	40	77	114	19
COLEOPTERA	0	0	0	0	0	0	0	0
HYMENOPTERA	0	1	4	0	1	1	0	0
HOMOPTERA	0	0	1	1	0	2	1	1
LEPIDOPTERA	2	0	0	0	0	1	1	0
HEMIPTERA	0	0	0	0	0	0	0	0
THYSANOPTERA	0	1	1	0	0	0	0	0

	Trap Creek,d/s X-8-95		Trap Creek,d/s X-12-95			Trap Creek,d/s X-22-95	
	1	2	1	2	3	1	2
EPHEMEROPTERA	0	2	2	1	0	0	0
PLECOPTERA	17	4	1	3	2	0	0
TRICHOPTERA	2	2	0	0	0	0	1
DIPTERA	46	116	30	16	33	17	120
COLEOPTERA	0	0	0	0	0	0	0
HYMENOPTERA	1	3	0	0	0	0	0
HOMOPTERA	1	1	0	0	0	0	1
LEPIDOPTERA	0	2	0	0	0	0	0
HEMIPTERA	0	0	0	0	0	0	0
THYSANOPTERA	0	0	0	0	0	0	0

	Trap Creek,d/s X-29-95			Trap Creek,d/s XI-7-95		Trap Creek,d/s XI-19-95	
	1	2	3	1	2	1	2
EPHEMEROPTERA	0	0	0	0	0	0	0
PLECOPTERA	3	1	0	3	0	0	3
TRICHOPTERA	0	0	0	0	0	0	0
DIPTERA	17	65	96	20	45	27	23
COLEOPTERA	0	0	0	0	0	0	0
HYMENOPTERA	0	2	0	1	0	0	0
HOMOPTERA	0	0	2	0	0	0	0
LEPIDOPTERA	0	0	1	0	0	0	0
HEMIPTERA	0	0	0	0	0	0	0
THYSANOPTERA	1	0	0	1	0	0	0